

FORM SENSE: ITS DEVELOPMENT AND ASSESSMENT

IN PRE-SCHOOL CHILDREN

by

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Thesis submitted for the Degree of
Doctor of Philosophy in the Faculty
of Social Sciences.

University of Edinburgh.

September, 1968.



ACKNOWLEDGEMENTS

I would like to express my thanks to the following people:

The W.H.Ross Foundation (Scotland) for the generous financing of this study

Dr. R.Lakowski, M.A., Ph.D., of the Psychology Department, Edinburgh University, for his encouragement and for his helpful supervision throughout the project

Dr. C.R.S.Jackson of the Eye Clinic, Royal Infirmary, Edinburgh, for his assistance and interest

The Edinburgh Corporation Departments of Education and Health, in particular Mr. Barnes, and Drs. Craig and Willieson, for their co-operation

Dr. W.O.Petrie of the Edinburgh Corporation Department of Health for refracting the nursery-school children

Miss McLaren, Nursery School Supervisor for her interest and her permission to work in the nursery schools

The Headmistresses and staff of the nursery schools for their kindness

Dr. Hannu Voipio of the University Eye Clinic, Helsinki, for helpful discussion

Mr. J.Rae, D.A., of the Visual Laboratory, Psychology Department, Edinburgh University, for his help with diagrams and illustrations

Mr. J.Gordon of the Psychology Department for help with apparatus, and Mr. P.Aspinall, M.Sc., and Mr. J.R.Burns, B.Sc., both of the Visual Laboratory for their advice and help

Mr. A.McDonald of the Department of Ophthalmology, Edinburgh University, and Mr. Hughes of Kodak Ltd., for help with photography

and the typist, Mrs. Linn.

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1. INTRODUCTION TO THESIS

Of recent years, many authors have been concerned with the assessment of vision in the pre-school child. To a great extent they have been interested in the validity of existing methods of measurement and in the many problems encountered in testing the young subject. Also, there have been those who have repeatedly emphasised the importance of the early detection and treatment of eye problems. Among those who have been concerned with the need for early ascertainment of visual deficiency are HEIMANN (1905), MORGAN et al., (1952), ALLEN (1957), DEERING (1958), JONKERS (1958), RYCHENER (1958), FINK (1959), SHERIDAN (1960), KAIVONEN (1963), DOLEŽALOVÁ (1964), BLACKHURST & RADKE (1966), HATFIELD (1966), and MORRISON (1966).

Detection of Amblyopia.

In particular, some authors have emphasised the problem of Amblyopia and the need for its early detection. These include BOCK (1960), SAVITZ et al., (1964), KITTREDGE & CUNNINGHAM (1965), TAUBENHAUS & JACKSON (1965), and DAVENS (1966). This emphasis has generally been accompanied by an explicit recognition of the fact of visual development (ALLEN 1957, FINK 1959, and DAVENS /

DAVENS 1966). In addition, concern has been expressed as an appeal for widespread screening of the pre-school child (KAIVONEN 1963, DAVENS 1966, and HATFIELD 1966).

Definition and Classification of Amblyopia:

Amblyopia is defined as "reduced visual acuity without ophthalmoscopically detectable anomalies of the fundus" (van NOORDEN 1967). Since a number of conditions fit this definition, it is important to differentiate between the types. AMBLYOPIA EX ANOPSIA (amblyopia from disuse) is the commonly used generic term for all of these conditions. In this respect, it is not strictly an accurate description since not all reduction in vision of this general form is due to disuse. For example, strabismic amblyopia is presently thought of as being caused by active cortical inhibition of impulses from the deviated eye. In this instance, the resulting reduction in vision is not caused by disuse, and the condition appears to be reversible. This category of impairments has been referred to as AMBLYOPIA OF EXTINCTION (PARR 1962), to distinguish it from Amblyopia ex Anopsia, which is an irreversible reduction in vision of eyes deprived of normal stimulation early in life. Parr has termed this latter condition AMBLYOPIA OF ARREST, since it is caused by arrested development due to either inadequate environmental stimulation (eg. darkness) or to congenital anomalies. /

anomalies.

It is thus important to distinguish between two categories of reduced visual acuity: Amblyopia of Extinction i.e. a functional loss due to probable cortical inhibition, and reversible if detected at an early age, and Amblyopia ex Anopsia which is the irreversible form of marked reduction in vision caused by arrested visual development due to early disuse of the system. Many studies, therefore, have been directed towards the detection of reversible amblyopia. When the loss of function has been discovered by means of reliable visual acuity tests, attempts can then be made to reverse the effect of the inhibitory condition. When vision has returned to the eye, the fault (a deviation, or a significant refractive error particularly myopia) can then be dealt with.

The need for vision testing in the pre-school years is apparent. To wait until the child is school-age and can competently perform visual tests might be the means of rendering the extinction amblyopia as irreversible as the Amblyopia of Arrest. The problem of the early detection of amblyopia, therefore, becomes one of testing the visual acuity of the pre-school child.

Definition of Visual Acuity:

Visual acuity has been defined in many ways depending /

depending on the type of test used in its assessment, but most of these definitions make reference to "the resolving power of the eye" and "the ability of the eye to discriminate details". Three components of visual acuity are generally recognised. These are: the MINIMUM VISIBLE which is the smallest areal extension of light visible (this is a function of both size of stimulus and intensity of illumination and has been equated with LIGHT SENSE), the MINIMUM SEPARABLE which is the smallest visual angle under which one can separate two objects, and the MINIMUM COGNOSCIBLE or FORM SENSE. The last is a measurement of the functioning power of the human eye, faced, as in everyday situations, with both simple and complex forms to discriminate and to respond to in a meaningful way. Such a method of assessment will involve many of the complex factors which determine visual perception. In this case, visual stimulation may interact at a cortical level with past associations, wishes, needs, general intelligence etc., to comprise what has been termed the SENSE OF FORM. In adults, this 'sense' is comparatively stable with more or less predictable stimulus-response visual sequences. But in children one must consider the stage of development of visual perception in order to ascertain the degree to which Form Sense has advanced.

Since /

5.

Since the purpose of this study is to trace the development of FORM SENSE in the pre-school child and to direct its valid assessment, it is important to consider the problems of VALIDITY and RELIABILITY with reference to the testing of this age group (three-five years).

Reliability and Validity:

Deficiency in communication and the distractibility of the pre-school child will affect the reliability of any subjective test however valid. The variability of attention, motivation, etc., may cause the child's performance to fluctuate, and the reliability of the test will reflect the skill of the administrator in stabilising these factors. If standard conditions are adhered to, reliability should be increased. The problem of validity, however, is more intractable. It suggests the need for referral to some objective criterion. If a truly objective assessment of visual acuity was possible, the problem would be minimised. The ideal towards which visual acuity tests in general aspire, is an assessment of visual efficiency as demonstrated in everyday situations. This is exemplified in the use of letter charts in adult testing. Here, the person is required under experimental conditions, to perform a visual task often imposed on him in his daily activities. Visual acuity as defined by the Snellen chart is determined /

determined, not simply by the minimum visible angle of one minute of arc (as has often been imputed to Snellen), but rather by the smallest letters which can be read at a certain distance:- "We take as unit for comparison the recognition of letters, seen at an angle of five minutes " - SNELLEN 1864 (2nd ed.). (For a full account of the Optometric Principle, see Appendix I.) This appears to be a valid means of vision testing in the majority of literate adults (though there are wide differences in reading ability even among adults, and the differences in legibility of the letters themselves have been attested to - RABIDEAU 1955).

Similarly in the case of assessing the vision of the young child, a definition of acuity should be derived from a task representative of the type of visual encounters the child is likely to make in everyday situations. It is easy to see why looking at pictures was chosen as a valid activity for measuring the visual ability of the child. However, only in so far as the child's response to these pictures is a simple function of the resolving power of the eye, can this situation be regarded as giving a valid visual assessment (validity here being defined in terms of clinical usefulness in selecting those children requiring early correction of defects). But the degree of complexity and variability found /

found in the responses of children to standard visual acuity tests, indicate that many other factors besides 'vision' are being utilised.

In the young child especially, all sensory function is greatly influenced by the child's level of general awareness. It is interesting to note that intelligence tests for the pre-school child are largely pictorial requiring visual discriminations of the representations. Ability to note and respond to small differences is often regarded as a manifestation of intelligence in the early years (for a fuller discussion, see the later section on Perception and Cognition p.12). It is largely the subjective response required of the child in these tests which will differentiate between levels of intellectual functioning, but the act of looking itself will not be outwith the cognitive influence. Yet the validity of a visual test depends on the ability to isolate the visual function for assessment. It would be impossible, however, to separate vision from 'the act of seeing' with its cognitive connotations, in view of the lack of a truly objective method of assessment (at best, known objective methods depend on a 'Psycho-optical' reflex requiring a degree of attention - see later section on Objective assessment p.219). Subjective methods of assessment for use with children therefore, in /

in order to approximate to the criterion of validity, must comprise simple stimuli requiring no complex perceptual processes, and necessitating only a simple response. The intelligence required (some is always necessary in a subjective test situation) should be minimal.

Validity, therefore, will be a function of the degree of simplicity of FORM SENSE required of the test where other factors which may intervene in a visual response are reduced and controlled. Thereafter, reliability will depend on the repeatability of those conditions controlling the psychological factors which contribute to the response in a given test situation.

The Development of Form Sense:

Whereas FORM SENSE is generally fully developed in the average adult, its appearance in the pre-school child is still governed by certain general laws of development. Thus ALLEN (1957) states:

"As visual acuity involves utilization of the sense of form, a sense more highly developed in some children than in others of the same age, attempts to evaluate the vision of three year old children in terms of the Snellen scale used for adults must not be taken too literally."

JONKERS (1958) also speaks of the differences in the "psychological sphere" between adults and children.

"The observational aspect of consciousness is still growing ... The whole of the contents /

contents of consciousness has an undifferential character ... Differences (between children of the same age) may be caused by the psychological structure and by the stage of development of the child." (Jonkers 1958).

CARLEVARO and OUILLO (1960) make a related point:-

"(These optotypes) must not be inter-confusable by the three year old who does not have such a certain experience of different objects as have adults. For example, thus it is that a St. Andrew's cross and an ordinary cross are one and the same thing at this age." (translation from the French)

Similarly, DOLEŽALOVÁ (1964) is concerned with the fact that ...

"the recognition of images and symbols by the child does not depend on visual ability alone, but also on a sense for recognising shapes which is not equally developed in all children of this age." (translated from Czech.)

Maturation and Learning:

This concern with the development of FORM SENSE is a question distinct from one of whether or not the anatomical and physiological condition of the child is equal to that of the adult. Changes at this basic level are known to take place in the early months and these must necessarily alter the capacity for discrimination. And such changes in function dependent on the completion of normal growth of the eye are a question of maturation. Undoubtedly, the change in discrimination objectively found in infants during the first six months correlates well /

well with this period of known anatomical development, and therefore would appear to be due to maturation of the underlying physiological mechanisms. But by the time the child is old enough to be tested by the conventional pre-school tests (on average, about three years) a great deal of learning has taken place.

Although discrimination is still subject to the limitations of the retina and visual system, it would appear that the perception of form (at least in its complex aspect) requires a learning process and the development of additional structures, probably cortical (although this is a moot point, and will be discussed more fully later). The pure perception of form, however, is further complicated and obscured by the fact that verbal ability and understanding are necessary to the child as tools with which to convey the features of this perception to the examiner.

Form Perception and Form Sense (Visual Acuity):

Therefore, a measure of the MATURATION of the visual system (which is ideally what a pre-school visual acuity test should achieve) is confused by the unequal rates of development in form perception, and further by the qualitative aspects of this development. The functional power of the eye and its ability to register details, and a description of the developmental stages of the ways in which the child assimilates visual /

visual information from his world, can be considered as distinct aspects of childhood vision.* Yet they are difficult features to separate in a study of the pre-school age group. Also it must be emphasised that the nature of any test of sensory function must be dictated by the way in which the given sensory development takes place. Therefore an understanding of the development of the "perceptual system" (that which regulates the WAY in which the child perceives) is essential to the assessment of the powers of the "visual system" (which governs the potential vision of the eye). If visual acuity is to be defined as discrimination, the above distinction is an essential one in the case of the developing child.

In this study, therefore, it has been thought advisable to differentiate between FORM PERCEPTION and FORM SENSE. Although the Sense of Form is almost synonymous with the term 'Form Perception', it is convenient here to refer to visual acuity or the resolving power of the eye as "Form Sense" (since this aspect of visual acuity has been frequently concentrated on in the /

* NOTE: Although sensory potential and the pattern of development of discrimination have been separated in this study, it is really an artificial division, for it is recognised that performance in any test of sensory function will be determined to a large extent by the characteristics of perceptual activity at a given age. Nevertheless, it has been thought necessary to separate these two aspects in a treatment of the problem, and it is hoped that further reading will make this distinction clearer.

the testing of young children e.g. picture charts). The term Form Perception will be reserved for that qualitative aspect of ways of perceiving (e.g. whether global or particular) characteristic of vision in the pre-school years.

This study of the development and assessment of Form Sense is, therefore, a study of the development of visual acuity of the pre-school child. A valid method of assessing this function, however, must be arrived at by means of a study of the way in which the child's perception of form develops (FORM PERCEPTION).

Perception and Cognition:

Mention has been made earlier of pre-school intelligence tests and of the fact that visual discrimination and recognition in the early years have been accepted as indices of intelligence. Since at this age, most of the child's information about his world must come through the senses (eyes in particular), it seems obvious that differences in general levels of visual awareness will be highly related to differences in levels of mental functioning. It may be that at first a global undifferentiated visual awareness is present in the child, and that this may gradually be refined to the perception of particulars, and that the cognitive process of forming more exact concepts may be effected partly by this improving discrimination.

At /

At this point, it is interesting to consider the Factor-Analytic studies carried out on the Stanford-Binet Intelligence Scale. McNEMAR (1942) found support for the view that a single common factor would explain performance on the test, but this did not preclude group factors operating at some age-levels. JONES (1949) analysed items at four separate ages, and the presence of group factors was clear. HOFSTÄETTER (1954) obtained three factors which comprehended intelligence test achievement in the early years:- for the first two years, variance of mental age scores is accounted for by a factor which he calls SENSORI-MOTOR ALERTNESS; PERSISTENCE is the factor operating between two-four years; and thereafter, the factor in operation is called MANIPULATION OF SYMBOLS.

The choice of test items in the pre-school years clearly demonstrate the operation of these factors e.g. Picture Vocabulary, Identifying Objects By Use, Block Building, Copying a Circle, Discrimination Animal Pictures, Response to Pictures, Pictorial Identification, Discrimination of Forms, Pictorial Similarities and Differences, etc. (TERMAN and MERRILL: STANFORD-BINET INTELLIGENCE SCALE, FORM L.M. 3rd Rev.1960). The high visual loading of test items at this age level is clear. In order to respond correctly, the child is required to

a) /

- a) look at the test item (this often involves a fairly complex discrimination),
- b) understand the precise meaning of the examiner's (E's) instructions, and
- c) respond correctly to the required task (generally either by naming or by matching).

For example, in one of the items at age four -

"Discrimination of Forms", the child is presented with a card on which are drawn ten geometric forms. Ten duplicate forms are then presented one by one to the child, and E instructs him to "Find me another one just like this" (indicating one of the duplicate forms).

Here, visual discrimination of the outline of the form is required, then the child must grasp the strict meaning of "just like" (this problem of verbal comprehension with reference to perceptual testing will be discussed later), and finally, he must select from the ten forms that one which exactly matches the given duplicate form. Another example is the item "Picture Vocabulary" which consists of eighteen 2" x 4" cards with pictures of common objects. On presentation of each card, the child is asked:- "What's this? What do you call it?" The two year old must score three to pass this item, but the criterion is raised to fourteen by Year IV. Thus valid intelligence test items showing high correspondence /

correspondence with the scale as a whole (biserial correlation - .75 and .79 respectively (1960)) greatly depend on accurate visual discriminations. And the correspondence between these types of task and the commonly-used pre-school visual acuity tests (Sheridan Letter-Matching test, the E test, and the wide range of picture charts - see Appendix II p.287), is clearly recognised.

The complex response, therefore, required of the pre-school child faced with an acuity picture chart, or faced with a letter to match against a duplicate card (and further complicated by distance), is very similar to that required of a child of the same age confronted by certain intelligence test items. However, the average child of four years should be capable (by definition of the age scale on which the Stanford-Binet test is based) of coping with this situation, but only the brighter three year old can be expected to perform at this level. To use conventional methods of acuity testing, therefore, especially at the three year old level, appears to introduce a strong cognitive component into the "Form Sense" required of a child of this age. It is true that with constant practice this factor will be minimised, but the dull child whose performance is impaired and who has in consequence poor "discrimination" /

"discrimination" (as indicated by his insufficient matching ability), may yet have a functioning visual system requiring no correction. His "perceptual system" may be retarded, and he may show signs of, for example, reacting to the over-all impression of the given stimulus at an age when he should be showing a well-established response to differentiated details; yet in spite of this, his "visual system" might be accurately recording the details of the given visual task. This, then is the problem, and it can be overcome only by understanding the developmental pattern in, for example, a matching response. One must not expect a three year old to differentiate between two very similar forms (as is found in some acuity tests) if his "perceptual system" is at a stage of development which dictates that he responds to the over-all similarity of the forms rather than to their differences. Again, it is recognised that what must be tested is "Form Sense" in its simplest representation, in order to reduce the need for cognitive interpretation and response. Thus, even very early in the history of pre-school testing, HEIMANN (1905) wrote:-

"(I have had the aim in view) to make the act of thought, which is closely connected with the act of seeing in every testing of the faculty of vision, as simple and easy as possible."

And /

And in 1919, EVANS notes:-

"One factor which seems to have been neglected by many authors is the one of the child's physical condition. The charts are stated to be arranged for children and illiterates, but it will be noted that they often present figures beyond the child's comprehension. Surely we need the help of what little understanding the child has."

JONKERS (1958) also speaks of the necessity of using optotypes

"to fit in with the child's ideas ... to draw the attention, and to direct the interest."

To sum up, for purposes of early assessment and diagnosis in clinical cases, the child's capacity for visual discrimination must be isolated. However, in most tests of sensory function, the child's cognitive awareness will play a large part in determining successful discrimination. What is required, therefore, is an understanding of the way in which visual perception develops (for this purpose, the particular aspect of perception studied, is that of black-and-white two-dimensional forms), so that one can select a task which does not demand a higher stage of "perceptual" development beyond the level of performance dictated by the child's rate of progress. Also, the cognitive influence on such a discrimination task must be minimised to allow for general administration. The present study is directed towards these ends.

2. A STUDY OF THE DEVELOPMENT OF FORM PERCEPTION.

1. Introduction

It has been said that a picture of the development of sensory function, will be determined to a large extent by the pattern of the development of mental function. If manifestations of sensory function are to be made dependent on the level of mental development (as in most subjective tests), then for a given "sensory age", the task which is used to elicit the required perceptual response must be in accordance with normal mental development at this age. What is the growth pattern of perception in the pre-school years? In what characteristic ways does the young child visually assimilate his environment (it is presupposed in these questions that the limits of the physiological system impose themselves on any act of visual perception)?

The old Nativist versus Empiricist controversy centred on whether form perception was innate in the human infant or whether it was acquired by a long process of learning and development. With the advent of more recent work on the form perception of infants and pre-school children, the debate has been resolved into the more realistic question of just how much the infant is given innately and how much he is required to learn. (Learning as used here, must not be confused with Maturation, for it is widely /

widely accepted that maturation of the visual system occurs with a consequent increase in the ability for visual discrimination. An innately given visual organisation which is refined and elaborated with growth can be distinguished from an increased ability for form perception as a result of learning.)

There are few exponents of the extreme positions now, but followers of the Gestalt school of perception have generally assumed an innate determination of their organisation principles (see ZUCKERMAN & ROCK 1957 - ref. WOHLWILL 1960) to the exclusion of any concentration on developmental changes. It is in opposition perhaps to this emphasis, that PAIGET among others has taken the other viewpoint, maintaining that these Gestalt principles of organisation are achieved only as a result of a prolonged developmental process (see WOHLWILL p.271). Work by the GIBSONS (1950, 1955), concentrates on this gradual process of learning, and recent Soviet Psychologists (see ZAPOROZHETS 1965) have stressed this same aspect. Most writers, however, are concerned with the development of form perception, with implicit, or in some cases (HERB 1962 (2nd ed. p.80-84), and FANTZ 1962), explicit reference to the presence of some innate perceptual organization (even if it is only the primitive figure-ground relationship - HERB 1962).

It is extremely difficult to obtain data on whether
or /

or not the rudiments of form perception are present at birth. What all writers must acknowledge, however, is that regardless of the ontological status of form perception, there occurs with age a change in the child's ability to perform perceptual tasks (be it as a result of maturation, or of learning, or of general increase in cognitive ability). Certain studies have shown characteristic ways of perceiving corresponding to different age groups, and these are the contributions which are relevant to the present work. Studies of the ontogenetic development of visual form perception are therefore of relevance to the present study, but the more ontological problem of the degree of innateness of form perception has little relevance here.

The review will take the form of a statement of theory and studies in this field arranged as far as possible according to the chronological development of the child. The present study of perceptual tests will then follow.

2. Review of literature: the development of form perception

It is convenient to divide the literature into the following aspects of form perception:-

- a) The perception of shape
- b) Scanning and eye movements in the perception of shape
- c) Part-whole perception.

a) /

a) The Perception of Shape or Pattern

Until recently, the common view was that the young infant could see only vague masses of light and dark, or was lacking in pattern vision until several months of age due to the immaturity of the visual system. Recent findings, however, have indicated a much better developed visual system in the newborn infant than had been previously assumed.

HERSHENSON (1964), in an attempt to further analyse those dimensions of stimulation which mediate preferential fixation in the newborn infant (original study and method by FANTZ), found support for Fantz's findings that these infants were able to discriminate stimulus dimensions other than brightness. However, commenting on Fantz's results, Hershenson added that it was not possible to state whether these dimensions could be classified as 'pattern', or whether they were more primitive in nature. The results were ambiguous in terms of their pertinence for a general theory of perceptual development, because the pattern-preference ordering could have been related to the brightness-preference ordering (the preferred intermediate brightness corresponded to the black and white patterned stimuli in Fantz's study).

STIRNIMANN (1944) using large patterns, obtained a consistent differential response to the patterns in infants of one day old. The results indicated that although /

although pattern vision may be poor in the early days of life, it is not absent.

FANTZ (1958, et al., 1962) was the first to use the differential fixation test of pattern vision. This is based, claimed Fantz, on the natural tendency of infants to fixate a patterned stimulus as opposed to a homogeneous one. Since it is a 'voluntary' attention, Fantz believed that this response represented a closer approach to the way in which pattern vision functions in most adaptive behaviour of the adult. He found positive results in infants from one to six months, demonstrating an early presence of pattern vision which nevertheless improved markedly with development and maturation in the first half year of life.

VENGER (cited by ZAPOROZHETS 1965) found that it was possible to elicit orienting differentiation to complex stimuli such as geometric figures in infants two to four months old. In this case, three-dimensional objects were used (prism, ball, cylinder, and cone) and duration of eye fixation was the measure of vision. The infants were familiarised with one object (prism) hung above the cradle, then when a pair of objects ^{as} ~~were~~ shown (prism and e.g. ball), the babies directed their eyes toward the new object and fixated on it for a longer period of time than on the old familiar object. The author concluded that this indicated a differentiation of the objects (average fixation /

fixation times:- familiar fig. 17.4 secs., new fig. 37.8 secs.). Venger went on to observe, however, that the movements of receptory organs in a three month old baby, are of an EXECUTIVE (controlling) and not of an EXPLORATORY (modelling) character. The function of the movements is to put the eye into an optimal position for observing the stimulus, and not to model the features of the stimulus. The change from executive to exploratory movements occurs gradually during the whole pre-school period.

LEWIS et al., (1966), criticised fixation times as a measure of preference, in the earlier methods. They claimed that the infant might fixate for longer periods of time, not because of a preference for a particular stimulus, but because of a desire to categorise an unfamiliar stimulus. "Stimulus interest", therefore, could refer to either preference or curiosity, and fixation time could not indicate which of the two processes was involved. (Nevertheless, irrespective of what motivated the fixation, it is clear that differential discrimination would have to have taken place before either process was operating.) The authors in their study found that FIRST FIXATION proved to be a more sensitive measure of differential attention than TOTAL FIXATION. On thirty-two infants, aged six months, however, response to six achromatic stimuli (a photograph of /

of a male face, a photograph of a female face, a schematic drawing of a male face, a bull's eye, a checkerboard, and a nursing bottle), confirmed the presence of pattern vision as in the previous experiments. Their results argued for important differences in effect of stimuli upon the pattern of fixation. Thus, two stimuli may elicit the same total fixation time, yet cause different patterns of fixation. There was a tendency for highly interesting visual arrays, such as faces, to cause the infant to look for longer periods of time before turning away, whereas other stimuli would elicit the same total fixation time but by means of a series of much shorter fixations. The authors also found sex differences in fixation and urged that all these factors be investigated in studies of perception and attention in the infant.

LING (1941) used a discrimination-learning procedure with children of six months. The stimuli were three-dimensional sugar-coated forms and he succeeded in showing discrimination between the various 3-D simple geometrical shapes. He also found that the discrimination response was hardly affected by changes in size or orientation of the correct figure. (Of incidental interest is his finding that a difficult discrimination between a circle and an ellipse was facilitated by first presenting the circle with an angular form. Transfer was then greater /

greater.) This study clearly indicates that the mechanisms for shape perception are functional at an early age (WOHLWILL 1960), but appear to require training for their emergence in a test situation. Wohlwill also comments that a probably important contributing factor to such early discrimination is the use of 3-D objects. Preceding studies, however, have shown a similar early discrimination of plane figures, but Ling's work represents a more mature level of involvement on the part of the young child, and is a definite indication of form discrimination (as opposed to the more tenuous, almost 'reflex' nature of previously mentioned methods using differential fixation).

MUNN & STIENING (1931 - ref. to by VERNON 1937), also described how a child of fifteen months, provided with a strong incentive to make visual discriminations, successfully made these discriminations. The child was first taught to discriminate between two boxes one of which had a black cross on a white diamond on the lid and which contained chocolate; the other which was empty had a black square on a white diamond. When the child had learned this discrimination, the orientation of the cross was changed and the background was varied many times, each time with no ill-effect on the child's correct response. It was concluded that the child /

child could appreciate small differences of form provided it was sufficiently motivated to do so.

GELLERMAN (1933 - ref. to by VERNON 1937) repeated this experiment using two two year olds. He showed that when sufficiently motivated (in this case, by a degree of hunger), the children were able to discriminate form (triangularity) independent of size, colour (black or white), type of triangle, and whether out-lined or solid. Also, it was found that quite small differences of form could be distinguished (e.g. a triangle from a trapezoid, and a circle from an ellipse-like figure).

Work with older children is more satisfactory in that a more positive measurement of discrimination is obtainable from them.

BOGUSLAVSKAYA (cited by ZAPOROZHETS 1965) has studied the development of the visual perception of pictures of concrete objects and of abstract geometrical figures in pre-school children (three - five years) and in a number of older children (five - seven years). She found that all the younger children and a number of the older group examined the object briefly, and subsequently created very incomplete images of the object, but could recognise the object fairly successfully by means of one or several typical features.

The work of LINE (1931 - ref. to by VERNON 1937), demonstrated /

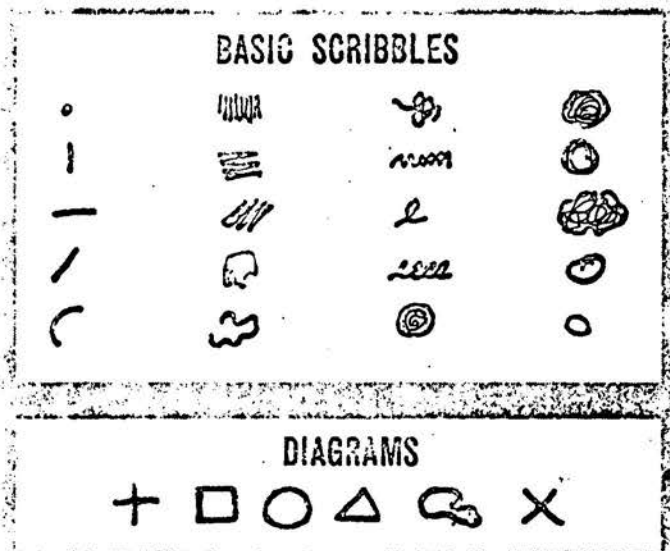


Fig. 1: Basic scribbles and geometrical diagrams (Kellog et al. 1965).

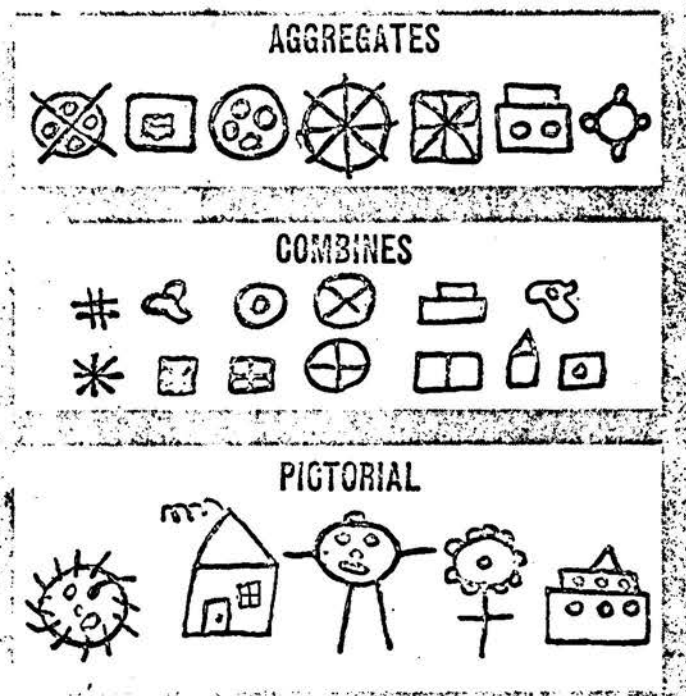


Fig. 2: Combines, aggregates, and pictorial representations (Kellog et al. 1965).

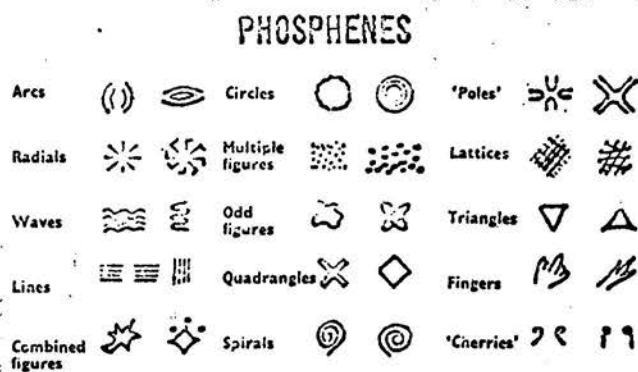


Fig. 3: Phosphenes (Kellog et al. 1965).

demonstrated that while children (aged four-five years) could perceive simple geometrical forms, they could not perceive their finer details. Using a method of card-sorting, he found that although the children were able to differentiate between a square and a circle, they could not see an irregularity in a round form, or distinguish between open and closed figures of the same general shape. VERNON (1937) comments later in the chapter (p.181):

"It is thus readily comprehensible that young children should show an apparent inability to discriminate small differences in the abstract sensory qualities of the surrounding visual field. This is in part a function of the immaturity of their intelligence - at least, of the intelligence which Binet attempted to estimate in his intelligence tests."

Kellog et al., (1965) have accumulated evidence that the visual perception of form and its two-dimensional representation (projection) are based on a limited number of simple elements for which there may be fixed and inherited neuronal pathways. Miss Kellog examined 300,000 drawings and paintings by pre-school children of American, Chinese, French, English, and Negro origin, and concluded that all children from the age of about two years make 'basic scribbles' (of which twenty have been identified), and five kinds of more geometrical 'diagrams' (see Fig.1). It is essentially from these twenty-five /

twenty-five basic elements that the child builds up 'combines', 'aggregates', and finally, pictorial representations (see Fig.2). Ability to scribble 'geometric patterns' does not exist in a child under the age of three. But after this, each child does not scribble an innumerable number of different patterns but only a limited number of 'basic' ones. From this, Kellogg et al., conclude that:-

"We are dealing here with the activation of pre-formed neurone networks in the visual system."

These basic scribbles and diagrams bear a strong resemblance to 'phosphenes': patterns 'seen' by electrical stimulation of the intact brain (see Fig.3), and since certain networks in the visual system (neurone chain oscillators or coincidence filters with small bandwidth within the e.e.g. frequency range) have been considered as a model for the phosphene phenomena, this may lead to the neurological clarification of the mechanism for pattern recognition.

GIBSON et al., (1962) studied the development of the ability to discriminate visually a set of 'letter-like' forms in children of four to eight years. The aim of the study was not only a quantitative comparison of different age levels, but also a qualitative developmental study of types of error as related to critical features /

features of letters. The discrimination task required the subject (S) to match a standard with an identical form from thirteen such forms, twelve undergoing four types of transformation:- (i) perspective transformations (2); (ii) rotation and reversal transformations (5); (iii) line to curve transformations (3); and (iv) break and close (2) (see Fig.4). Results indicated that there is the greatest developmental change between four-eight years in the tendency to confuse rotation-reversals, with line-to-curve errors showing the next greatest drop, perspective errors next, and topological errors least. Gibson argued that this improvement in discrimination between four-eight years is due to the children learning something about letter-like forms which makes better discrimination possible. The results suggested that what they learn are the features or dimensions of difference which are critical for differentiating letters. The differences between the developmental error curves for the four types of transformation, were interpreted in terms of a hypothesis of distinctive features. Features which have been critical for distinguishing objects in the past, are assumed to transfer to graphic discriminations, and discrimination learning continues for distinctive features of letters. Those features of graphemes which are not critical for distinguishing them, are learned more slowly.

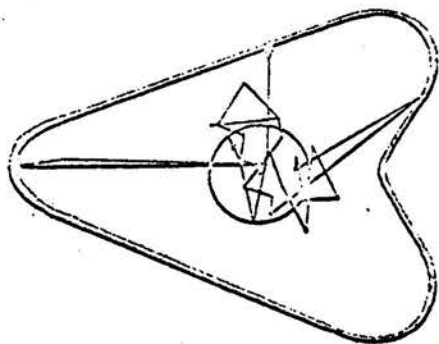


Fig. 5: Eye movements of 3 and 4 yr. olds (Zinchenko and Russkaya 1965).

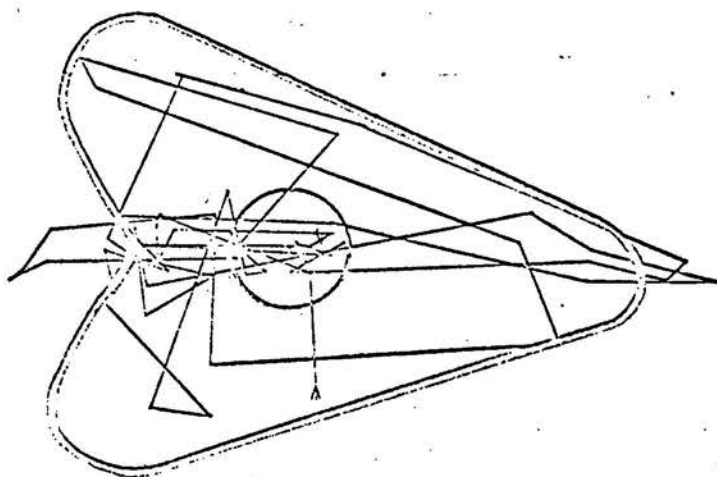


Fig. 6: Eye movements of 5 and 6 yr. olds (Zinchenko and Russakaya 1965).

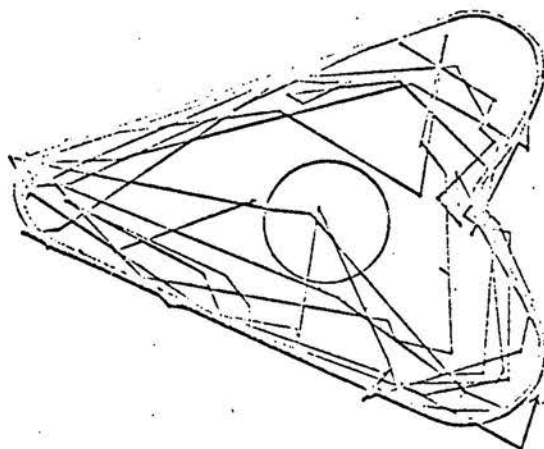


Fig. 7: Eye movements of 6 and 7 yr. olds (Zinchenko and Russakaya 1965).

It is appropriate to conclude this section with a quotation from WOHLWILL (1960):

"While form discrimination can be demonstrated fairly early in infancy, it is not a very potent aspect of the stimulus in the perception of young children."

b) Scanning and Eye Movements in Shape Perception

ZINCHENKO & RUZSKAYA (cited by Zaporozhets 1965) found that there is a great difference in the perceptive actions of children when they recognise a familiar object and when they see a new object. Zinchenko distinguished between 'actions of recognition' and 'acquaintance actions'. She studied the 'acquaintance actions', filming the eye movements of children of different age groups as they inspected figures of an irregular form 30x40 cm.. The figures were projected for twenty seconds on a screen that had a hole for a camera in the centre. The children were required to look at the screen attentively, so that they could recognise the figure among other figures later. The recordings showed considerable developmental changes in the character of perceiving 'actions'. With three and four year olds, the eye movements were few, the periods of fixation between the movements being much longer than in older children. The movements were contained within the figure and often centred around the camera which distracted the child (see Fig.5). In no cases did the eye follow the outline of the figure, and later recognition /

recognition was low: this seemed to be related to the primitive study technique. Even figures quite different in form were confused. With children of four-five years, eye movements were still mainly within the figure (see Fig.6), the number of movements were twice as great as in the younger group, and the fixation time was less. It appeared to the authors from the direction and length of movement, that the size and length of the figure were being measured. Although no movements were observed to systematically trace the outline, there were groups of fixation points related to the most specific features of the figure. This method of inspection achieved better recognition results than did the method of the younger children. Five and six year olds began tracing the outline, but again tended to look at the more salient part to the exclusion of other parts. These movements, however, seemed adequate to the task, since the majority of the five year olds gave correct recognition choices. The eye movements of the six-seven year olds traced the outline of the figure as if producing or 'modelling' its form (see Fig.7). Also, more movements across the figure were observed which were probably an attempt to gauge the area. As a result, 100% correct answers were obtained. Developmental changes of this kind were also found in other sensory areas showing a general developmental trend.

KERPELMAN & POLLACK (1964) studied thirty nursery children /

children between the ages of three and a half years and six years. Five irregular pentagons were used for a discrimination task. The facts emerged from a dimensional analysis of the data, that given full opportunity to examine the stimuli, younger children tended to use the bottoms of the pentagonal stimuli as discrimination cues, but a progressively greater role with age was played by top-to-bottom scanning. This is in keeping with GHENT's findings (1963) that the tendency of children to scan a form from top to bottom increases with age.

WCHLWILL & WIENER (1964) carried out an experiment to assess the validity of the view that spatial orientation played a weak role in the form perception of young children. The method used was a matching-from-sample task, where S was presented with a series of trials in which one choice stimulus was identical with the sample, while the other was the left-right or upside-down reversal of the same figure. The stimuli varied on the dimension of openness versus closedness, presence or absence of asymmetrically placed internal detail, and high versus low directionality. The contribution of these dimensions to discriminability of spatial orientation was of particular interest. In accordance with Ghent's scanning hypothesis, it was predicted that openness, directionality, and presence of detail would facilitate discrimination of orientation, since each of these stimulus characteristics should /

should operate to facilitate up-down scanning from a focal point, in comparison with closed, non-directional, or no-detail figures. Also up-down reversals were postulated to be more readily discriminable than left-right reversals (GHENT, 1963). This hypothesis is in accord with most prior evidence, but the results of the study by GIBSON et al., (1962) failed to confirm it. The results of Wohlwill & Wiener's study indicated that children were highly successful in differentiating stimuli on the basis of their orientation, in the perceptual-match discrimination task. It can be concluded, therefore, that an inadequate level of perceptual maturity in sensitivity to form orientation is not responsible for the difficulty which children of this age may encounter in the learning of differential responses to stimuli differing in orientation.

This data, therefore, point to the necessity of considering the kind of responses required of the subject in the study of perceptual skills and developmental changes in such skills due to learning or experience. The results fail to support the belief that pre-school children are notably deficient in their response to the orientation of a stimulus. Observations of their apparent inability, may be due to their response to salient features in the objects depicted e.g. the tail of /

of a dog, which would permit them to recognise the objects in any orientation. Therefore, upside-down looking, common to pre-school children, cannot be taken as evidence of their inability to respond to spatial orientation. The results corroborate and extend the findings of Ghent, and particularly support the view that discrimination of shape orientation in children is but a special case of the more general problem of the development of shape or form perception.

VURPILLOT (reported in the 6th Annual Report of the Harvard University Centre for Cognitive Studies 1965-66, p.9), studied the development of scanning strategies used in the judgement of similarity by young children. The group of sixty-eight children was divided into three, the average age of each division being 5.1, 6.7, and 8.9 years. The children were shown pictures of a stylised house, each with three rows of windows. These houses differed in some detail in the pattern of the windows, and each child was required to say whether the items of the pair were the 'same' or 'different'. The problem was whether improvement in discrimination and differentiation with age is due to a perceptual difficulty of young children to discriminate small details, or whether there was a different use of available information in the young child. A MACKWORTH eye-movement camera (described in the same report) was /

was used to record which areas of the pair of pictures were fixated and in what order. A correct judgement would be obtained by direct comparison between the six windows in one house and those in the other. As soon as a discrepancy was noted, a 'different' judgement could be given, but a correct judgement of 'same' would require a full comparison of the six pairs. There are two types of strategy that could be employed. The 'ideal' strategy which would minimise the load on memory, should start at the same point on each picture and successively compare each pair of windows. The other strategy is less satisfactory since it would place a greater load on memory. It would take the form of first looking at one picture as a whole, then looking at the second picture. Differences were noted in the way the three groups scanned the pictures. The youngest group deviated most from the ideal strategy. These children tended to glance at one picture then the other and make a single comparison the basis of their judgement. The result was a judgement of 'same' on the basis of a few details only. This was not due to a lack of understanding of 'same' and 'different', nor of an inability to discriminate small details. If the two pictures differed in a number of aspects, their strategy was as efficient as that of the older groups. Vurpillot attributed /

attributed the small amount of information gathered by these children to an unsystematic method of scanning (this she related in turn to defects in the child's spatial frame of reference.) The second group were also unable to get information systematically. Even when an early discrepancy was noted, they seemed to think that an answer should not be given until all the information was handled. The oldest group, however, used a strategy somewhere between the two forms. They compared groups of two or more windows at a time, but relied more on memory than an 'ideal' strategy would dictate. It also became clear that their field of vision was large enough to take in more than one window with a single perception, since accurate judgements could be made without the children having fixated on all the windows. Only the older children showed evidence of an adequate strategy for scanning and coping with the task of comparing small details. Thus it was concluded that inability to detect small details was not due to a failure of the perceptual mechanism but rather was due to an inadequate use of available information.

WANG CHIH-CHING (1965) based his work on observations of SHECHENOV that the movement of the eye has a decisive function in the process of producing the perceptive response. PAVLOV's reflex theory further explained this /

this question in a more scientific way: by its movement, the perceptive organ repeated and compared the characteristics of the perceived object, thus obtaining and 'reflexing' the shape of the object. Chih-Ching's study was an attempt towards greater understanding of the nature of children's perceptive movements by tracing the developmental changes of the perceptive movement itself. It was thereby hoped to explain the rule of development of the perceptive process in children. Eighty subjects, aged three, four, five and six years were divided into two groups according to the task required of them. Group I was involved in a task purely of OBSERVATION, whereas group II was required to RECOGNISE a previously inspected object. The stimuli, irregular geometrical diagrams 30x40 cm., were projected onto a screen placed 60 cm., from the child. The eye movements were recorded by cine-camera (16 mm., 8 frames per sec.), and the recorded cine film was analysed by a semi-automatic single frame projector. The author then traced the development of changes in path of eye movement with age for each of the two conditions - observation and recognition. The following general trend was observed: when children OBSERVED, the older the age, the greater the average scope of their eye movement. However, when RECOGNITION was required, the scope of the eye movement decreased as age increased, and the path of the eye movement /

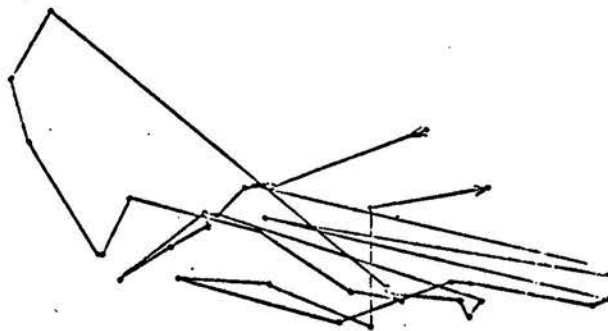


Fig. 8: Eye movements (OBSERVATION) of 3 yr. olds (Wang Chih-ching 1965).

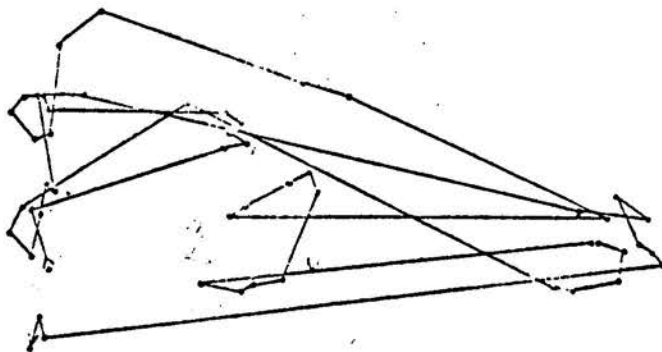


Fig. 9: Eye movements (OBSERVATION) of 5 and 6 yr. olds
(Wang Chih-ching, 1965).



Fig. 10: Eye movements (RECOGNITION) of 3 yr. olds (Wang Chih-ching, 1965).

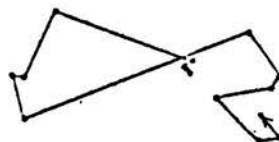


Fig. 11: Eye movements (RECOGNITION) of 5 and 6 yr. olds
(Wang Chih-ching, 1965).

movement tended to be simplified, its correspondence with the shape of the object being less significant. The range of eye movement was limited to a small section of the diagram (see Fig.8). The development was further analysed as follows: I. OBSERVATION:- three years: activity of the eye was less and the path was confused tending towards unidimensional (scanning towards opposite directions - see Fig.9). There was no correspondence with the outline (especially with the characteristic features). Four years: a similar pattern was observed; only a few children followed the outline and were subsequently able to distinguish the shape from others. Five and six years: here the path of the eye movement basically corresponded to the outline of the diagram (see Fig.10), though the six year olds were generally better. Later identification, description, and drawing of the object observed, accurately reflected the degree of correspondence between the path of scanning and the shape of the stimulus. II. RECOGNITION:- three and four years: the eye followed a complex path with greater scope of movement (see Fig.11). Five and six years: the eye movement was simpler and the scope less. Correspondence between outline and eye movement was less significant at this stage for accurate recognition. Improvement in recognition occurred with age, paralleling the /

the types of movement characteristic of the different ages.

c) Part-Whole Perception of Form

VERNON (1937 p.178) noted with reference to work by the Gestalt psychologists that the perception of young children differs greatly from adults in this respect, that they are likely to perceive the field as a series of undifferentiated meaningful wholes...

"... children tend to ignore details, and their perceptions are vague, fluid, inaccurate, and liable to modification in accordance with subjective tendencies."
(VERNON 1937 p.178).

SEGGERS (1926 - ref. to by VERNON 1937), noted the tendency among children to ignore details of complex forms and to see them as simple meaningful wholes. This characteristic he termed SYNCRETISM. Children of three-five years named incongruous pictures (drawings of animals with the head of one animal and the body of another) according to the body and general appearance, without hesitation.

SOKHINA (cited by ZAPOROZHETS 1965), continuing an experiment of LURIA's, showed that children of three-seven years without special teaching, could not discriminate purely visual elements of a complex form. For example, they could not say of what parts a given figure consisted. However, after a series of exercises in constructing /

constructing structures out of elements of different form and size, the children began making a visual analysis of the figure. Also, the results of this teaching were transferred to new situations.

In this section, we are concerned with the perception of part against whole features of complex forms. The main source of information on this developmental aspect of perception is studies of age changes in RORSCHACH responses (e.g. AMES et al., 1953). There is general agreement that perception proceeds from a global unstructured percept in early childhood, through a phase when detailed part-perception predominates, to a final stage where integration of both types of percept can take place. Rorschach findings, however, being somewhat equivocal because of lack of control over either stimulus or response (Wohlwill 1960 p.273), required confirmation from a more systematic approach.

DWORETZKI (1939) cited by Wohlwill 1960 p.273, used meaningful designs made up of meaningful parts. The youngest children responded to the design as a whole, while details predominated in the perception of older children. Adolescents and adults, finally, incorporated both aspects in their responses.

SELINKA (1939) also cited by Wohlwill 1960 p.273, constructed a task similar to the KOHS Block-Design Test. In this case, a circular pattern was presented to the subject /

subject who was then required to reproduce the pattern by means of four blocks, each of which contained a quarter of a circle made up of different kinds of patterns on the different sides. The rationale was that the way in which the pattern was then reconstructed would demonstrate the child's attention to detail. The results showed a considerable improvement from the kindergarten level where the component parts were ignored, through successive age groups up to ten years. (Reproduction of a whole from parts, however, requires more than simply the way in which a total is perceived. This is probably why age changes were considerable. This is more than a perceptual task of form perception since it requires a spatial factor of intelligence similar to that required of the Kohs Block test. The spatial array requires to be broken down and each of the quarters perceived in isolation and correctly represented - what appears to involve a cognitive process.)

There is sufficient evidence, however, for the difficulty experienced by young children in perceiving small details in complex but meaningful wholes. But when the whole does not represent a strong aspect of the stimulus, it is claimed, even young children can respond to details. VAN der TORREN (1907), cited by Wohlwill 1960 p.274, presented children with drawings of familiar objects /

objects at progressively increasing levels of completeness. The child on each presentation was required to (a) identify the object, and (b) point out those parts added since the previous exposure. Identifications improved with age as would be expected, but the detection of the added details was almost perfect at the youngest age level (four years). The children were here required to concentrate on the parts with obvious success. But when this study was replicated by SCHÖBER & SCHÖBER (1919), differing from the original study in that only internal details were added to in successive exposures (each exposure containing the complete outline of the object), it was found that the presence of the completed outline of the object interfered with correct recognition of the detail. In this case, correct recognition of parts increased from 36% to 88% between the ages of four and eight years.

MEILI (1931) (see Wohlwill 1960 p.274) has concluded from these studies that the young child cannot attend to both part and whole at the same time. The degree of structure present in the stimulus will determine to which of the two aspects the child will respond. With strong or simple wholes, the whole will be perceived, whereas for weak or complex wholes details will be responded to. Wohlwill, however, concludes that since an operational definition of strong versus weak wholes is /

is missing, this finding is of limited usefulness. Wohlwill surmises that these two factors might be reduced to those of continuity of outline, and degree of internal redundancy. This would bring the problem under the framework of Information Theory.

ELKIND & KOEGLER (1964) carried out a study on 195 children, from four to nine years of age. In their stimulus-drawings, both parts and wholes had independent meanings. Their contribution was in the direction of a systematic exploration of Piaget's theory of Perception (PIAGET & MORF 1958) as it applies to meaningful materials. According to Piaget, the perception of the young child is 'centred' in the sense that its organisation is dominated by the Gestalt-like principles of good form, closure, etc. Piaget calls these FIELD EFFECTS. With age, however, the child's perception is freed from the domination of Field Effects, and the older child is able to differentiate the elements of a configuration. This was originally formulated with relation to illusions and the constancies, but the present study was an attempt by the authors to determine whether the decentering of perception could also be demonstrated in the part-whole aspect, when both parts and wholes have different and independent meanings. The authors commented that only one preceding study, that of MEILIDWORETZKI (1956) used figures in which both parts and wholes /

wholes had different meanings. In this study, a regular increase with age in the percentage of subjects who saw parts and wholes was found. It was also found that wholes were perceived at an earlier age than were parts, and that a majority of the subjects (75%) did not perceive both part and whole until adulthood. One possible explanation of these findings, according to Elkind & Kogler, was that the stimuli used were such as to favour a 'centering' on wholes rather than on parts. The parts were often superimposed resulting in an indistinct representation. Also the parts and wholes were drawn schematically to the exclusion of some common identifying characteristics, and also the parts were sometimes objects unfamiliar to children. The figures used in Elkind & Kogler's study contained parts taken from nursery-school books, were clearly drawn, were not superimposed, and were generally easier to recognise than the wholes. These authors found a regular increase with age in the percentage of children who perceived both parts and wholes (as in the previous finding). But they found that children of average and above average intelligence perceived parts more readily than they perceived wholes (contrary to the previous findings). Also, they found that a majority of nine year old children were able to make a part-whole integration. The authors concluded that /

that when the figures used are such that the laws of closure, good form etc., favour the perception of parts, the parts will be perceived at an earlier age than the wholes. In view of these results, those of Meili-Dworetzki (that wholes were perceived earlier than parts) cannot be attributed to inborn tendencies to perceive wholes. These earlier findings, according to the authors, seem to be accounted for by the fact that the figures used, favoured whole over part perception. On the other hand, their own results were in accord with the decentring position. In their experiment, decentring involved a shift of focus from whole to part or vice versa. The authors proceeded to describe the regulational mechanisms of this decentring in part-whole perception, likening it to the problem of forming disjunctive classes on the plane of concept-formation. The child must combine for example, the percept of a head with the percept of an apple and must then attribute percepts to the one perceived form. It would seem that the perception of both parts and wholes in the one form would require the formation of a new percept - an 'apple-head' or a 'head made of an apple'. In fact, stages in the development of this perception were found to be analogous to those found in conception: a complete centration, giving way to an intuitive decentration (separate perception of wholes and parts without any attempt at integration) /

integration), and finally resulting in a complete regulational decentration where part and whole were simultaneously perceived, but were also perceived as and attributed to the same form e.g. a man made of fruit. Age changes, therefore in part-whole perception involving the identification of meaningful figures were found to be in accord with Piaget's developmental theory of Perception, i.e. field effects will determine the perception of parts or wholes, rather than an inborn tendency to perceive in one way rather than in the other.

d) Summary

It has been seen that the characteristic features of the development of form perception in the pre-school child, are important considerations in the construction of a test of visual function. The above review of literature reveals many pertinent characteristics of this perception.

It was shown how the early presence of pattern vision in infancy, gave way to a demonstrable discrimination of form in the six month old child when sufficient incentive was provided. However, with no specific incentive, children of four-five years could perceive simple geometrical forms, but could not perceive their finer details. It was found that perceptive actions (eye movements) of acquaintance became increasingly effective /

effective with age, capable of tracing the outline of a given figure only by the age of seven years. Increased accuracy of later recognition of the given figure appeared to be causally related to this effective scanning. Also in a comparison task involving pairs of almost identical figures, scanning strategies only reached an adequate level by the age of eight-nine years. Inability in younger children to detect small details was due to an inadequate use of available information. Another study noted an increased tendency with age to scan from top to bottom, and an emphasis on the bottom area of the stimulus in the perception of the younger children.

Earlier studies were generally agreed upon the finding that form perception proceeded from a global unstructured percept to a more detailed perception. It was later concluded that young children could not attend to both part and whole at the same time, and that the degree of structure present in the stimulus would determine to which of the two aspects the child would respond. When the stimuli used favoured the perception of parts, these would be perceived at an earlier age than the wholes. Earlier results, it was claimed, therefore, could not be attributed to 'inborn' tendencies to perceive wholes but rather to the field effects of the stimulus configuration.

The most important/^{finding}emerging from several of these studies /

studies, is that deficient performance of younger children on certain perceptual tasks which appeared to be due to a deficiency in the visual mechanism, proved on further examination to be due to other causes. For example, the observation that children have difficulty in learning a differential response to stimuli differing in orientation was found to be due, not to an inadequate level of perceptual maturity, but probably to the child's response to salient feature of the object permitting recognition in any orientation. It was found that children were in fact highly successful in differentiating stimuli on the basis of orientation in a perceptual-match discrimination task (WOHLWILL & WIENER 1964).

Similar evidence against the cause of a deficient visual response in the pre-school child being a failure of the perceptual mechanism, was found when the scanning at this age was discovered to be inadequate to the task. The result was an inadequate use of available information (VURPILLOT 1965-66).

Another similar finding was provided by the results of SOKHINA (ref. ZAPOROZHETS 1965). Without special teaching, young children were unable to discriminate the elements of a complex form. After training, however, they began making a visual analysis of the figure /

figure - confirmation that the perceptual apparatus was functioning at this age, but in this particular instance not being fully utilised.

VERNON (1937) has partly attributed the apparent inability to discriminate small differences to the immaturity of intelligence (as defined by the Binet tests). Whatever the reason for the young child's inability to use visual information to the full, it appears clear that the information is indeed available mediated by a functioning visual and perceptual mechanism. This is a very important point and must be kept in mind if one is to assess the power of the visual system in the pre-school child. The level of form perception required in such a task is thus an important consideration.

3. The Study: The development of form perception in the pre-school years.

a) Introduction

The two types of response which are obtainable from the pre-school child and which have been utilised as subjective tests of visual acuity, are NAMING and MATCHING. It has already been noted that to use such responses is to introduce a definite cognitive component into acuity testing, and that consequently no child should be presented with a test of sensory function in the form of a cognitive task beyond his level of development. The present /

present section, therefore, is an attempt to trace the development of these two types of response to a variety of perceptual tasks in the pre-school years (three-five years). It will be recalled that the aspect of form perception to be isolated in this study, is the perception of black and white two-dimensional forms under various conditions of presentation. Eight such perceptual tasks (six requiring a matching response and two a verbal response) were given to a total group of over 200 nursery school children enrolled in five Edinburgh Corporation Nursery Schools and Classes and drawn from a comprehensive range of socio-economic backgrounds. The ages of the children ranged from two years six months to five years six months. The eight perceptual tests were as follows:-

- Test 1 : Screening Test - Form Matching Ability
- Test 2 : Two-choice Form Matching - Geometric Shapes
- Test 3 : Four-choice Matching - similar shapes of decreasing area
- Test 4 : Pictorial Form Discrimination - pairs of pictorial forms
- Test 5 : Form Matching - Pictorial forms versus Abstract symmetrical shapes
- Test 6 : Letter Matching
- Test 7 : Part-Whole Perception (- naming response)
- Test 8 : Simplified Objects (- naming response).

b) /

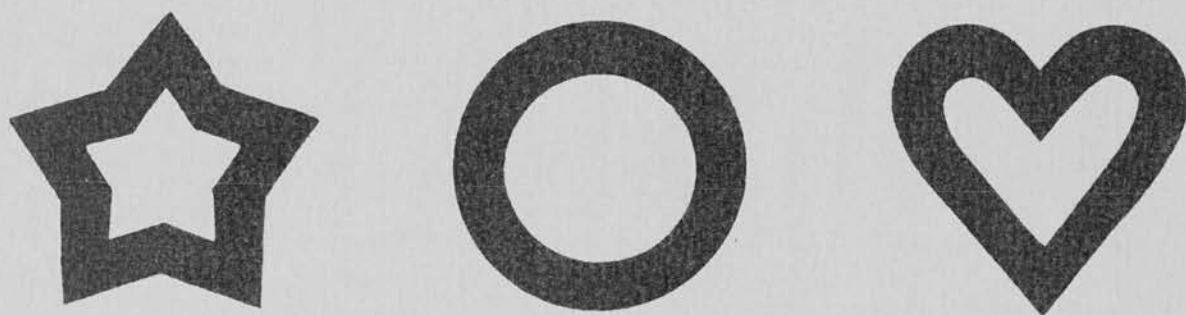


Fig. 12: Ryba Optotype.

b) Test 1 : Screening Test - Form Matching Ability

This test was based on the Ryba Optotype (see DOLEŽALOVÁ 1964) and consisted of three black shapes - an outline star, a circle, and a heart, on a white background (see Fig.12). Topologically the figures were of the same general closed shape, but were sufficiently different as to present no discrimination problem to the younger children. What was being screened was the children's ability to match a sample card against a test card (the response required in the five subsequent perceptual tests). The total group of 210 children were therefore given this test, and the different samples for the ensuing tests were drawn from those children who could successfully perform this simple matching task. The children were presented in turn with the key card (5" x 8") on which were printed the outline drawings, each drawing being inscribed in a 2" square and composed of lines $\frac{1}{8}$ " thick. The key card was placed in front of the child at right angles to his direction of sight and at reading distance (about 1½ft.). The child was allowed to inspect the key card for ten seconds and was then encouraged to name the objects depicted. Most children could do so successfully. On a space below the key card, each of the test cards were placed in turn, in random order. E placed the smaller test card in position and said to the child: "Look at this picture (pointing /



pointing to the smaller test card) and find me the one on this card (pointing to the larger key card) just like this one here." If the child hesitated, E pointed to the test card and said: "What is this?" When the child replied e.g., "A star", E said: "Now, you are going to find me the star on this card." E continued with this procedure until the child had grasped what was required of him. E then presented the two remaining test cards in the same way. Most children could match the test cards correctly, though a few of the younger children required additional help. There were five cases of negativism or non-response, and twelve children were unable to carry out a correct matching procedure even after extensive explanation and trials. These children were subsequently excluded from the sample. It was thereby established that the remaining group of children could perform a simple matching response, and that any future errors would be a function of the required process of discrimination or fluctuations in attention, rather than one of difficulty in understanding what was required in the matching response. These children who had passed the screening test then formed the group from which samples for subsequent tests were drawn.

c) Test 2: Two-Choice Form Matching - Geometric Shapes

Description:

The /

The symbols for this test consisted of eight geometric shapes. Each shape was paired with every other one, giving twenty-eight presentations of a two-choice matching situation. The paired shapes, each one inscribed in a $1\frac{1}{2}$ " square and separated from each other by a length of 2", were drawn in black ink on twenty-eight white cards (each 5" x 8") and the outlines were $\frac{1}{16}$ " thick. The order and pattern of presentation are shown in Fig.13.

Subjects:

190 nursery-school children from the original sample were used. The age range and distribution were as follows:-

<u>Age</u>	<u>Frequency</u>
2.0. - 2.11.	5
3.0. - 3.11.	62
4.0. - 4.11.	88
5.0. - 5.6.	<u>35</u>

N = 190

Table 1 : Age distribution of subjects

Presentation:

The twenty-eight key cards were placed in turn before the child at reading distance and perpendicular to his line of sight and the child was allowed to inspect each card for 5". Below each, was placed the smaller test /

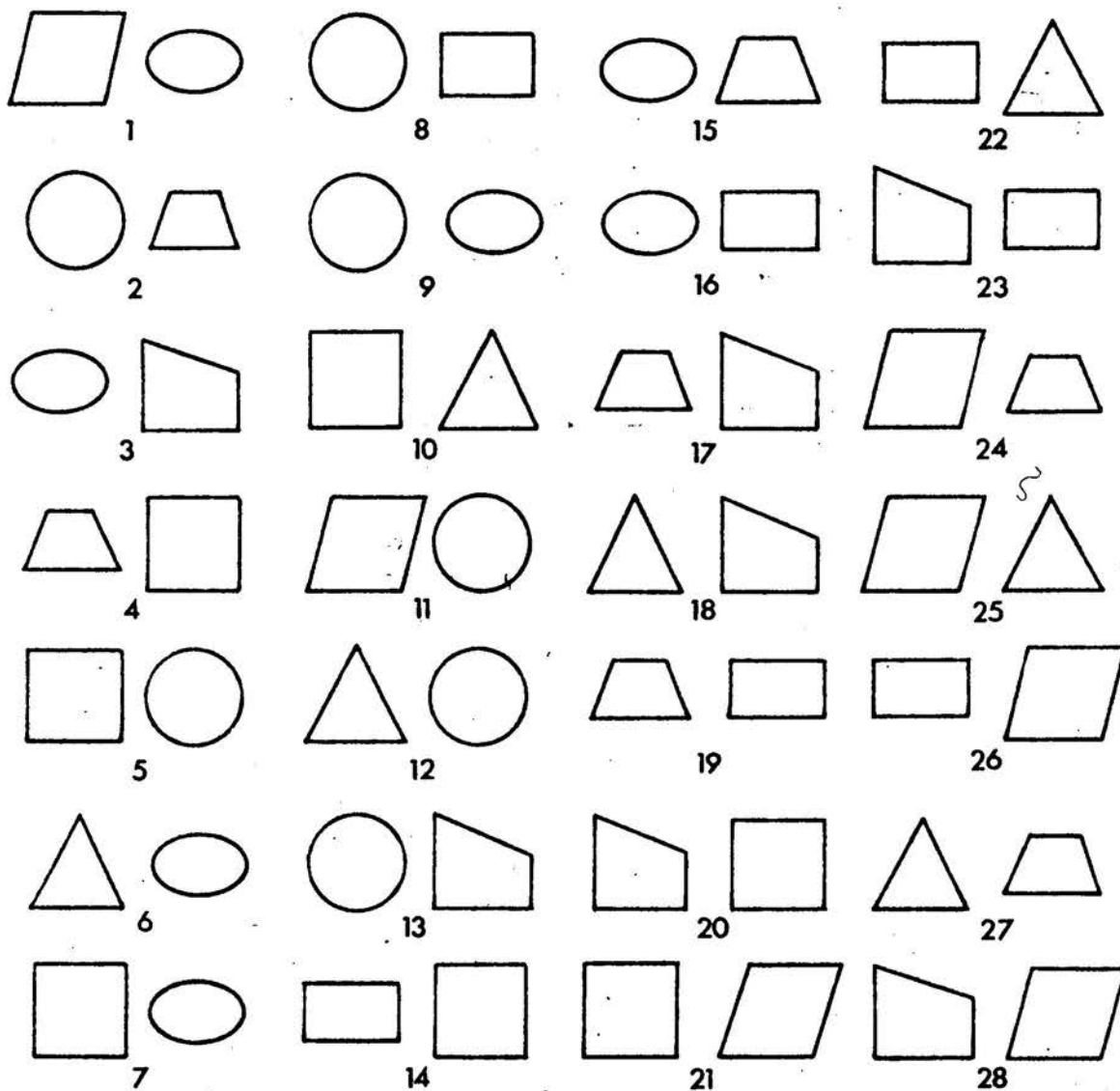


Fig. 13: Test 2 - order of presentation.

test card on which was drawn an identical form to one of the pair on the key card. E pointed to the smaller test card and said: "Look at this picture, and find me the one just like it on this card (pointing to the larger key card)". If S hesitated or seemed confused, E repeated the instructions, but did not assist S in any other way. Frequently, the children pointed to both shapes on the key card, in which case E repeated: "Point to the one just like this one." The child's match was noted together with any observations E thought relevant to explain the child's choice. Any relevant verbalisations which the subjects made were also noted. The twenty-eight presentations were made as lively and as speedily as possible to ensure that the child was not fatigued or bored by the procedure.

Results:

All scores were corrected for chance guessing by subtracting the error score from the total number correct. Correct matchings were each given a score of one, and a wrong choice which was quickly and spontaneously corrected by the child was given a score of half.

Pearson's product moment correlation (r) (see Appendix III p.330 for formula) between chronological age and test score (corrected for guessing) was .46 and the Standard Error (σ_r) of this statistic was .057 (see Appendix III p.330 for formula). The correlation coefficient /

coefficient like all statistics is subject to errors of sampling. The size of the Standard Error indicates how much risk is taken in letting ' r '* stand for ' \bar{r} ' (population parameter). In fact there is little risk in using ' r ' as an estimate of the population parameter (\bar{r}) if the sample is large and ' r ' is large (GUILFORD 1956 p.179). A Standard Error of .06 means that the correlation of .46 would not deviate from the population ' \bar{r} ' by more than .06 with a confidence indicated by odds of two to one. Also, there would be less than five chances in one hundred that in samples of this size the sample ' r ' would depart more than .118 (.06 x 1.96) from the population value, and less than one chance in one hundred that the sample ' r ' would depart more than .155 (.06 x 2.58) above or below it (for a discussion on these levels of confidence, see GUILFORD 1956 p.167-168). Consequently, the obtained ' r ' seems securely placed in a region removed from zero or negative correlations. Thus, corrected for possible errors of sampling, the obtained correlation between age and score represents a strong positive relationship.

Means /

* NOTE: In order to demarcate symbols for statistical procedures from the surrounding text, these symbols have been placed in commas (except when they appear alone in parenthesis) thus: ' r '. It should be noted, however, that these symbols normally occur without these demarcations, and will be found as such in Appendix III.

Means (M) and Standard Deviations (σ) - (for formulae, see Appendix III p.330) together with Standard Errors of these statistics (σ_M and σ_σ - for formulae, see Appendix III p.330) for each of the three main age groups are given in the following table:-

<u>AGE GROUP</u>	<u>MEAN (M)</u>	<u>ST.ERROR</u> (σ) <u>OF MEAN</u> M	<u>STANDARD</u> (σ) <u>DEVIATION</u>	<u>ST.ERROR</u> (σ_σ) <u>OF STANDARD</u> <u>DEVIATION</u>
3.0. - 3.11.	24.54	0.39	3.01	0.27
4.0. - 4.11.	26.17	0.17	1.57	0.12
5.0. - 5.6.	26.44	0.27	1.56	0.19

Table 2 : Means (M), Standard deviations (σ), and Standard errors of scores for three age groups

The reliability of the means are given by the Standard Errors. As in the case with the Standard Error of the correlation coefficient, these standard errors represent the amount by which the given statistics can be expected to deviate from the population means. There is a one in three chance that the means of the three samples will deviate from the means for the population age groups by more than .39, .17, and .27 respectively. Confidence intervals for the .05 and .01 levels for each of the three age group means are given as follows:-

AGE /

<u>AGE GROUP</u>	<u>CONFIDENCE INTERVALS</u>	
	<u>AT .05 level of</u> <u>confidence</u>	<u>AT .01 level of</u> <u>confidence</u>
3.0. - 3.11.	25.2 - 23.78	25.54 - 23.54
4.0. - 4.11.	26.5 - 25.84	26.6 - 25.74
5.0. - 5.6.	26.97 - 25.91	27.14 - 25.74

Table 3 : Confidence intervals (.05 and .01 levels) from the Means of three age groups

Thus, all hypothetical population means for the three age groups differing more than 1, .43, and .7 respectively from the three sample means (+ or -) can be rejected with only one chance in one hundred of being wrong in so doing. Similarly, the odds are two to one that hypothetical population standard deviations will not deviate more than .27, .12, and .19 from the obtained standard deviations for each of the three age groups respectively. Also all hypothetical population ' σ 's for the three age groups differing more than +/- .7, .5, and .31 from the sample ' σ 's can be rejected at the .01 level of confidence.

't' tests^{*} for differences between pairs of the means (see Appendix III, p.330 for formula), in the three age /

* NOTE: Justification for use of a 't' test for samples of such unequal sizes, is found in SIEGEL 1956 p.154. Even though the formula used is that of the ordinary 't' test, the test is not used in this case as a parametric test, for the assumption that the populations are normally distributed with common variance is not necessary.

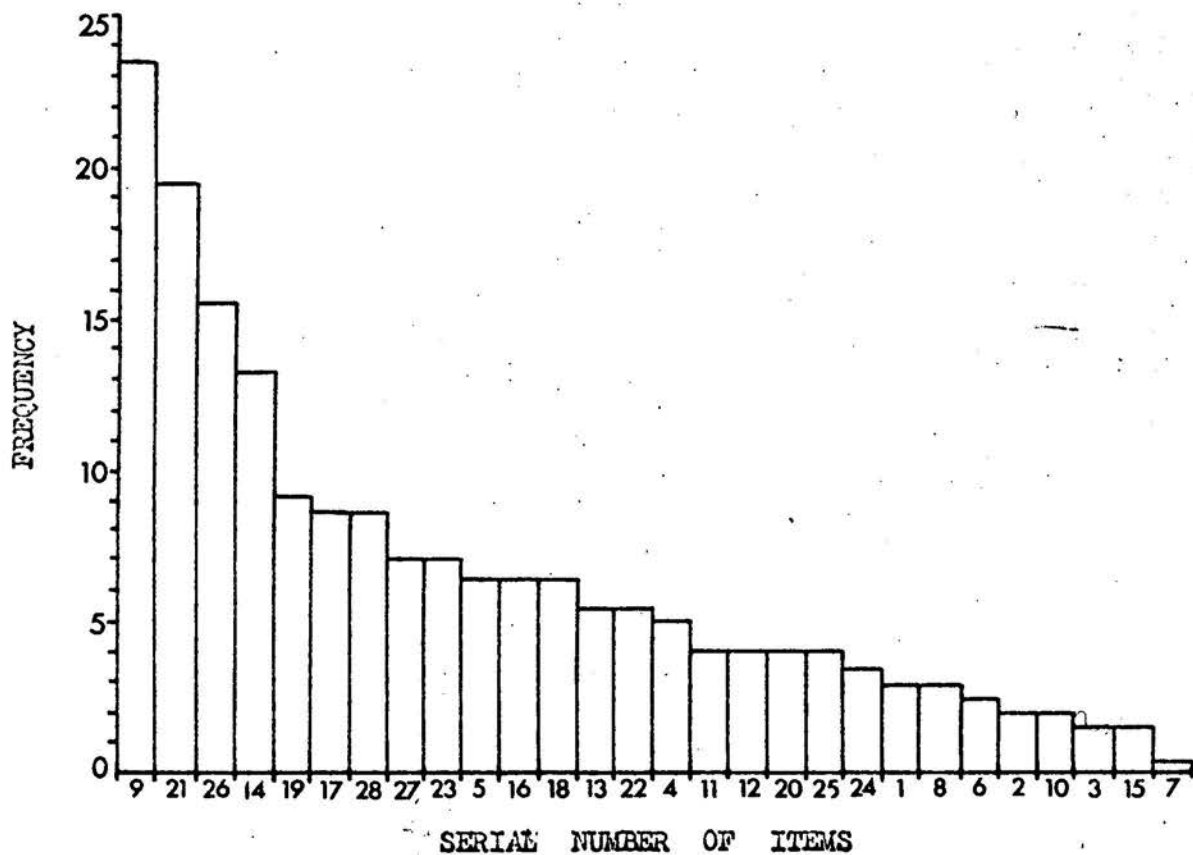


Fig. 14: Frequency distribution of error scores (Test 2).

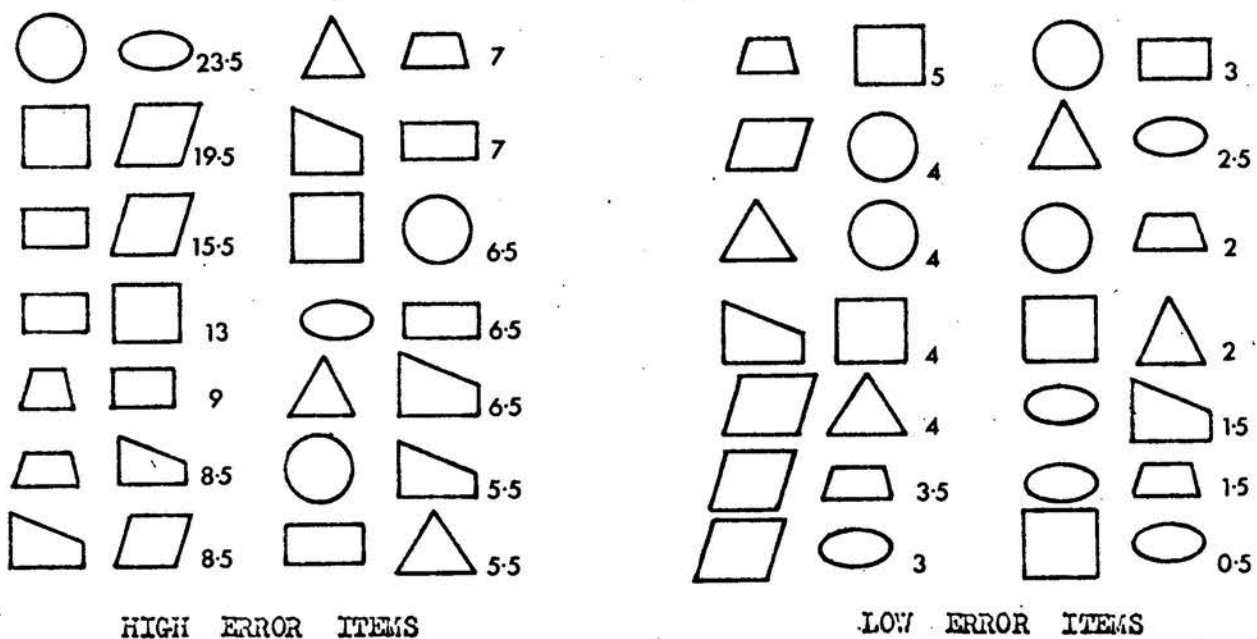


Fig. 15: Analysis of items in high and low error categories (Test 2).

age groups are given in the following table together with the probability levels for such differences to have occurred by chance in samples of these sizes:-

<u>AGE GROUPS</u>	<u>N</u>	<u>t</u>	<u>DEGREES OF FREEDOM (df.)</u> $(N_1 + N_2 - 2)$	<u>PROBABILITY</u> (1-tailed test)
3.0. - 3.11. and 4.0. - 4.11.	62 88	4.25	148	$\gg .01$
4.0. - 4.11. and 5.0. - 5.6.	88 35	0.83	121	$< .05$
3.0. - 3.11. and 5.0. - 5.6.	62 35	3.46	95	$\gg .01$

Table 4 : t tests and significance levels
between pairs of Means in the three
age groups

The null hypothesis, viz., that the pairs of means are not significantly different, can be rejected therefore at the .01 level for the means of the three and four year olds, and for those of the three and five year olds, but the means of the four and five year olds are not sufficiently different to reject the null hypothesis.

The frequency distribution of error scores (un-corrected) is shown in Fig.14. In Fig.15, an analysis of those items in the high errors and those in the lower errors is given. There was no apparent practice -effect.
or /

or effect of fatigue on the scores of items in the second half of the presentation.

Discussion: The correlation between chronological age and test score is a positive one, highly significant for a sample of this size ($N=190$). This indicates the existence of a substantial relationship between age and score in a positive direction. Therefore, there appears to be a developmental improvement of performance in such a two-choice matching situation. Age, however, is not the sole determinant of performance as indicated by the non-perfect correlation. Other factors such as attention (fluctuations in which are frequent at this age), random guessing generated by a sort of negativistic attitude to the situation, and level of mental development are all possible influences in test performance. The last of these factors is probably the most relevant. Provided the total sample of children was in the average range of intelligence, the relationship between score and age probably would have been clearer. But since the sample was large and randomly drawn, it is likely that there would have been a small section of very bright and very dull children in the group. The cognitive component in a matching-from-sample procedure has already been noted. Thus it appears likely that certain three year olds who were mentally in advance of the average level of performance for their years, were scoring at a four and five year /

year old level, whereas dull five year olds were performing at an age level much lower than their years. This probable intervention from levels of cognitive functioning would serve to reduce the correlation between age and score, although obviously there was a sufficiently large number of children in the average range of intelligence for the positive relationship to emerge. Also, it would appear that after age four, there was not a great deal of improvement in the mean score, and five year olds were making similar scores to those children in the latter part of the four year old group. This, too, would have an effect on the positive relation.

Differences between means for the age groups similarly reveal the same trend, though it appears that the ability to match forms such as these was well developed on average by the age of three years; thereafter, little improvement seems to have taken place. However, the means for the youngest and the two older age groups were significantly different beyond the .01 level, although the difference between those for the four year olds and five year olds did not achieve significance at the .05 level. This finding is probably accounted for by two reasons: firstly, only the first half of year five was represented, and secondly, the performance appeared to be approaching its ceiling by year four, so that in the later years there was little provision for /

for improvement in such a task.

Standard deviations show a reduction with age, indicating that in addition to a general improvement of scores with age, the scores became more closely grouped around the mean. This points again to a more uniform level of ability in this type of task after age four.

From the analysis of pairs into high-error scorings and low error scorings (see Fig.15), the eight highest and eight lowest were taken for further analysis. Group I consisted of items 9, 21, 26, 14, 19, 17, 28, and 27, while Group II was made up of items 1, 8, 6, 2, 10, 3, 15, and 7. From a simple visual analysis it is clearly seen that the pairs in Group I are more 'similar' than those in Group II. The following analysis was an attempt to define this 'similarity'. The pairs in each group of items were rated according to four dimensions in which dissimilarity was thought to lie, as in the following table:-

Group I Items (High Error Scores)									Group II Items (Low Error Scores)							
Nos.	9	21	26	14	19	17	28	27	1	8	6	2	10	3	15	7
Unequal No.Sides in the items of the pair.								1	1	1	1	1	1	1	1	1
								= 1							= 8	
Round v.Straight sides.								= 0	1	1	1	1	1	1	1	1
								= 6							= 7	
Unequal Areas.	1			1	1		1	1	1	1	1	1	1	1	1	1
								= 6							= 8	
Unequal Heights.	1			1	1		1	1	1	1	1	1	1	1	1	1
								= 5							= 6	

Table /

Table 5 : Rating of pairs on four dimensions
of dissimilarity.

It can be seen that each pair in the lower-error group generally divide on each of the four points, whereas the high-error group pairs, show less over-all divergence, but more particularly show this lack of difference on the first two aspects viz., unequal number of sides, and round versus straight-sided. The scores on the other two aspects, however, though slightly less than those of the low-error group, nevertheless are still well represented. Dissimilarity in the low-error group seems to be accounted for more by unequal number of sides and round versus straight-sided figures, than by unequal areas and unequal heights. The most confusing factors in the high error pairs, therefore, appear to be related to similarity in outline viz., equal number of sides in each pair, particularly in pairs of four-sided and one-sided figures.

While on a purely visual level, absences of these dissimilar dimensions of themselves might be responsible for the incorrect matching, there is the possibility of another relevant factor, viz., one relating to categorization by the young child. At an early age, the child's verbal concepts are generally undifferentiated e.g., both a cat and a dog are frequently called 'bow-wow' /

'bow-wow' in early childhood. It is possible that this generalisation also is extended to visual categories; so that when a very young child looks at e.g., a circle and an ellipse, he may well 'see' the same gestalt quality of 'roundness'. It is therefore also possible that the less bright children in the present sample (functioning as they would be at a lower mental age than their chronological age), were unable to further differentiate between the two shapes. Even if the difference between the two shapes is being faithfully recorded in the visual system, for the young child this difference may not be sufficiently significant to elicit a differential response to each item of the pair. Both items of the pair, therefore, may have achieved a type of 'equality' in this respect that both are being responded to in the same way. It was noted during the course of testing in the present instance that a few children pointed to both figures on the key card saying: "That's the same, and that's the same." This response occurred most frequently with the highest error-scoring items viz., circle and ellipse, and square and parallelogram.

Another possibility, however, is that interference in discrimination is occurring at a verbal level. This possibility is present on two accounts. Firstly, the young child's understanding of the instructions "just like" /

like" may be a much more general type of comprehension than that of an adult. "Just like" might assume for the child a meaning closer to the common use of "similar" (meaning "the same in some respects"). If this were so, then either of the figures in many of the pairs would be "just like" the test figure. The second point, however, refers to verbal labelling of the figures on the part of the child, which could possibly interfere with discrimination. It has often been noted that there is a tendency among young children verbally to transform two-dimensional forms into a corresponding concrete object e.g., a circle is often labelled 'ball', and a square often is named 'box'. This tendency was again noted in the present test situation, e.g., when a few children were presented with the rectangle and square (item 14) they spontaneously said "Two boxes". If, when the child inspected the key card, this kind of 'identity' was conferred on each item of the pair, then when another 'box' was presented on the test card, either of the key card items would be "just like" the one he was being required to match. This will be discussed more fully in the next section, where the response to 'similarity' (equal number of sides) was studied in greater detail.

Summary:

1. There was a significant improvement in performance on /

on a two-choice matching task from three-five years, although the ability was found to be well advanced by age three, and showed little improvement after the age of four years.

2. Not only age was involved in this performance. Other factors such as general ability and attention were supposed to account for any discrepancy between age and score.

3. Scores became more homogeneous with age, clustering more closely about the mean. This indicated a more uniform level of ability after age four.

4. Analysis of those items on which a high number of errors were made compared with items on which a small number of errors occurred, showed that 'similarity' of the pairs in the high-error group could be broken down further into a dimension of equal number of sides, particularly round shapes paired together and four-sided figures occurring in pairs. In addition to visual 'similarity' two types of verbal 'equalities' were noted as perhaps being responsible for confusion. This aspect of 'similarity' is to be investigated more fully in the next section.

d) Test 3 : Four-Choice Form Matching - Similar Forms

Description:

Four basic outline shapes were used in this test - circle, square, triangle, and cross. These were inscribed /

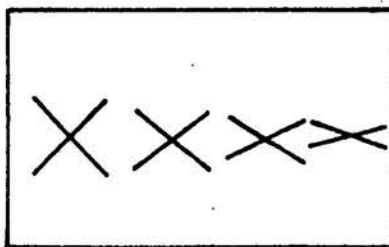
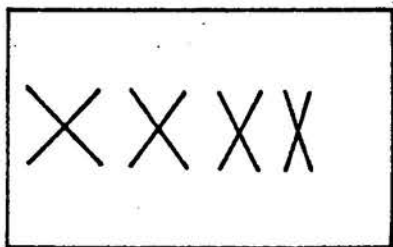
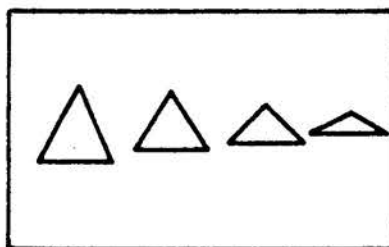
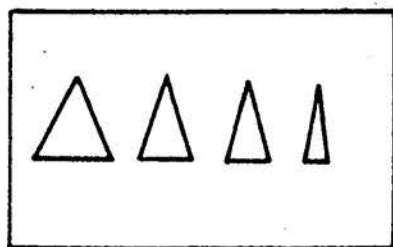
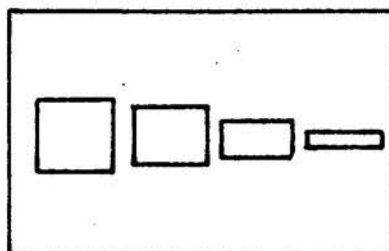
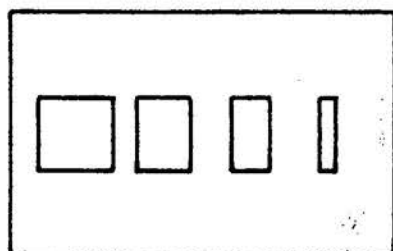
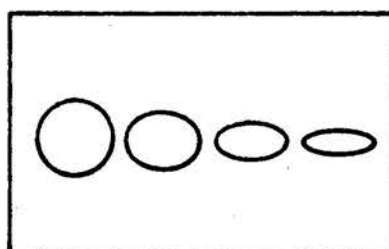
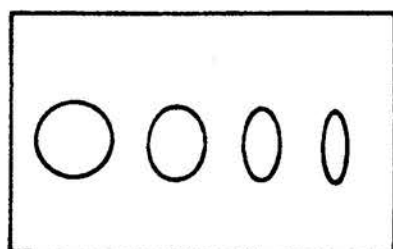


Fig. 16: Test 3 - eight key cards.

inscribed in a 1" square in black ink on eight white cards (5" x 8"), so that each figure appeared on two cards. On one of the cards, each basic shape was grouped with three derived shapes of decreasing width, and with three derived shapes of decreasing height on the second card. The resulting eight sets of four figures were placed 1" apart on the middle of the cards, so that each card had one of four basic shapes together with three derived figures of either decreasing height or decreasing width (see Fig.16). The outlines of the figures were $\frac{1}{16}$ " thick, and the areas of the sixteen shapes were as follows:-

Circle: 0.78 sq."; Ellipse 1: 0.59 sq."; Ellipse 2: 0.39 sq."; and Ellipse 3: 0.2 sq.".

Square: 1 sq."; Rectangle 1: 0.75 sq."; Rectangle 2: 0.5 sq."; and Rectangle 3: 0.25 sq.".

Triangle 1: 0.5 sq."; Triangle 2: 0.375 sq."; Triangle 3: 0.25 sq."; and Triangle 4: 0.125 sq.".

Cross 1: inscribed in 1 sq."; Cross 2: in 0.75 sq."; Cross 3: in 0.5 sq."; and Cross 4: in 0.25 sq.".

Eight key cards with four figures on each card resulted in thirty-two possible matching situations. Thirty-two smaller test-cards were prepared (2" square) on which each shape represented on the key cards was reproduced /

reproduced.

Subjects:

From the original sample screened on the first form-matching test, 188 nursery-school children were drawn. All of these children had previously performed the two-choice matching test (Test 2), so that each child had had the same amount of test experience in this respect. The age range was as follows:-

<u>AGE</u>	<u>FREQUENCY</u>
2.8. - 2.11.	2
3.0. - 3.11.	57
4.0. - 4.11.	88
5.0. - 5.6.	<u>41</u>

N = 188

Table 6 : Age distribution of subjects.

Presentation:

The test cards were randomly numbered and subsequently were presented in the same random order. At each presentation, the appropriate key card was placed facing the child at reading distance. E drew the child's attention to the card and allowed him to inspect it for five seconds. The particular test card was then placed below the key card, and E pointed to the smaller card saying: "Look at this picture and find me the one just like it on this card (pointing to the larger key card)."

The /

The thirty-two test cards were presented in turn in this way. After each presentation, the child's response was noted together with any verbalisations the child made, and any observations on his performance.

Scoring:

A score of one was given for a correct match, and a score of half was given for a match on either side of the correct figure. It was also noted whether this near but incorrect match was in the direction of over-estimation or underestimation of the given test-stimulus. All scores were then corrected for guessing. This was complicated by the fact that a score of half on the test cards corresponding to the two outside figures could only be obtained from one choice, whereas a choice on either side of the two inner figures would give a scoring of half. Also, for each outside figure, either of two choices out of the possible four, could lead to a score of zero, whereas for each inside figure only one choice from the four could give a zero score. The scores for the test cards corresponding to the two outer figures were therefore corrected on a different basis from those for the two inner ones. For the outside positions, zero scores were totalled for the test card presentations throughout the series corresponding to these positions, and three-quarters of these scores were then subtracted from the number of correct scores in these /

these positions. Zero scores were then totalled for test cards corresponding to the two inside positions on the key cards, and these were then subtracted from the total number correct in these positions. For example, if out of a possible sixteen correct scores on figures in the two outside positions on each key card, four scores of zero were obtained, this would give a corrected score of twelve - ($\frac{3}{4}$ of 4) = nine. And if for the figures in the inside positions a score of twelve was obtained with a zero score of four, this would give a corrected score of twelve - four = eight. The total corrected score in this example would therefore be nine plus eight equals seventeen out of a possible thirty-two.

Results:

Pearson's product moment correlation (r) between age and test score, was .48. The standard error of ' r ' was .056. Thus an obtained correlation as large as .48 for samples of this size, would not be expected to deviate more than .06 from the population ' \bar{r} ' with a confidence level of two to one. Also, there would be less than five chances in one hundred that in any sample of this size, ' r ' would deviate (above or below) more than .118 from ' \bar{r} ' and less than one chance in one hundred that a difference of .115 would be obtained between ' r ' and /

and ' \bar{r} ' (see GUILFORD 1956 p.167-168). Thus the obtained ' r ' is significantly placed in a region of definite positive correlation.

Means and standard deviations for each of the three main age groups, together with the standard error for each statistic are given in the following table:-

<u>AGE GROUP</u>	<u>MEAN (M)</u>	<u>ST.ERROR OF MEAN (σ_M)</u>	<u>STANDARD DEVIATION (σ)</u>	<u>ST.ERROR OF (σ) STAN- :DARD DEV.</u>
3.0. - 3.11.	16.37	1.45	10.88	1.01
4.0. - 4.11.	22.84	0.7	6.52	0.49
5.0. - 5.6.	26.14	1.03	6.5	0.72

Table 7 : Means (M), Standard deviations (σ), and Standard errors of scores for three age groups.

The standard errors of the means for each group yielded the following confidence intervals for the .05 and the .01 levels:-

<u>AGE GROUP</u>	<u>CONFIDENCE INTERVALS AT .05 level of confidence</u>	<u>CONFIDENCE INTERVALS AT .01 level of confidence</u>
3.0. - 3.11.	19.17 - 13.57	20.07 - 12.67
4.0. - 4.11.	24.14 - 21.54	24.64 - 21.04
5.0. - 5.6.	28.14 - 24.14	28.84 - 23.44

Table 8 : Confidence intervals (.05 and .01 levels) from the Means of three age groups.

All hypothetical population means for the three age groups differing more than 3.7, 1.8, and 2.7 respectively above or below the sample means could be rejected at the .01 level (i.e. one chance in one hundred of this occurring). Similarly, all hypothetical population standard deviations differing more than ± 2.61 , 1.26, and 1.86 respectively could be rejected at the .01 level of confidence.

't' tests of the difference between pairs of mean scores from the three age groups, together with the probability levels for such differences to have occurred by chance were as follows:-

<u>AGE GROUPS</u>	<u>N</u>	<u>t</u>	<u>DEGREES OF FREEDOM (df.)</u> ($N_1 + N_2 - 2$)	<u>PROBABILITY</u> (p)(1-tailed test)
3.0. - 3.11. and	57			
4.0. - 4.11.	88	4.46	143	» .01
4.0. - 4.11. and	88			
5.0. - 5.6.	41	2.68	127	> .01
3.0. - 3.11. and	57			
5.0. - 5.6.	41	5.218	96	» .01

Table 9 : t tests and significance levels between pairs of Means in the three age groups.

The null hypothesis concerning the non-significance of all differences between the above pairs of means could all /

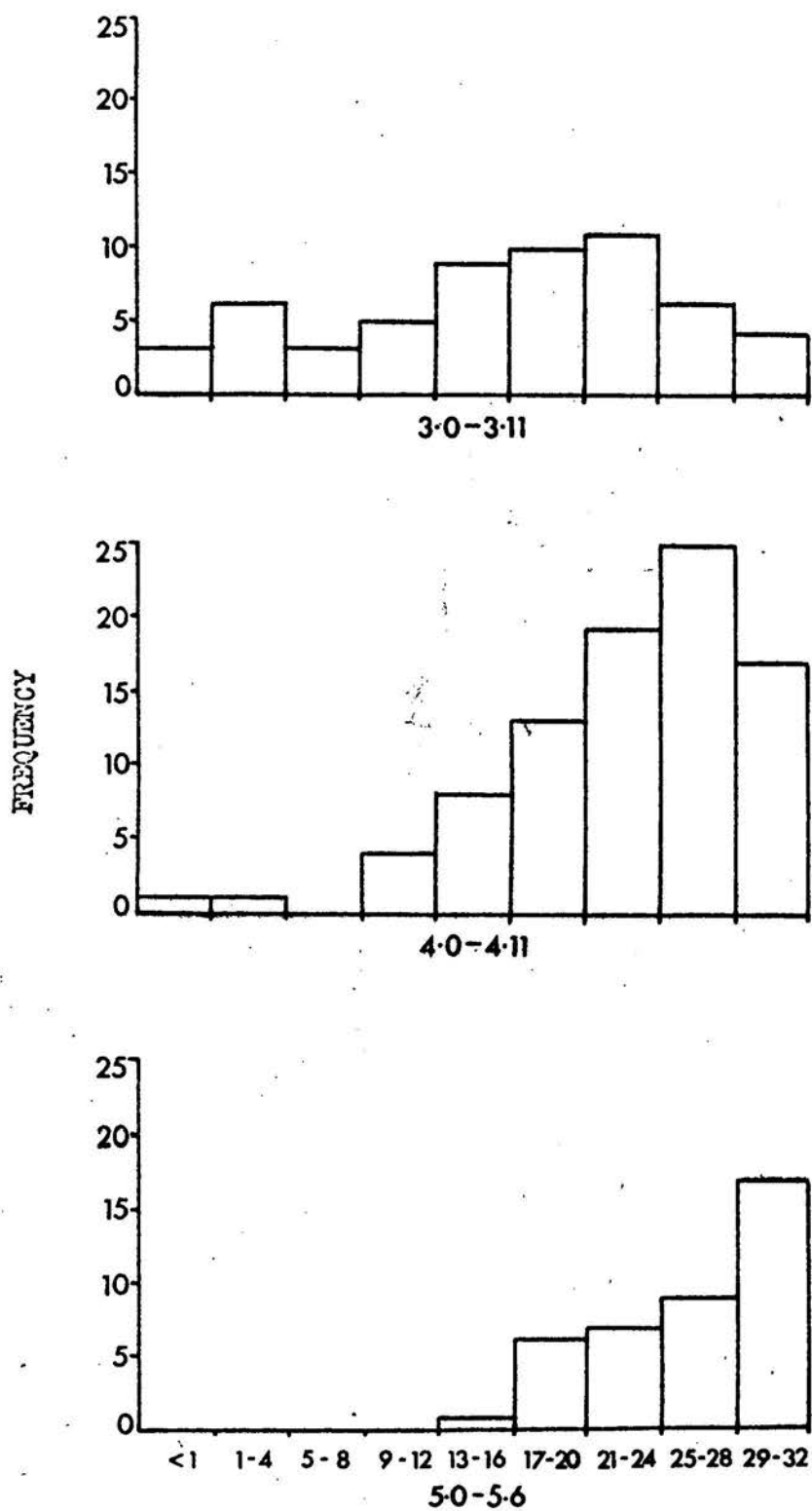


Fig. 17: Distribution of scores for each age group.(Test 3).

all be rejected well beyond the .01 level of probability. (The same justification for the use of a 't' test for these samples of unequal size applies here as in the previous test - see Note, p. 57.)

The distribution of scores for each age group is shown in Fig.17.

A 't' test for comparison of means of overestimated and underestimated matches to the test figures in the total error scores for each age group is given below:-

<u>AGE</u>	<u>M</u> (Overest.)	<u>M</u> (Underest.)	<u>t</u>	<u>df.</u>	<u>p</u> (2-tailed test)
3.0. - 3.11.	5.33	5.11	.386	56	<.05
4.0. - 4.11.	4.74	4.49	.641	87	<.05
5.0. - 5.6.	3.41	3.10	.51	40	<.05

Table 10 : t tests between Means of overestimated and underestimated matches in the three age groups.

The null hypothesis i.e. that there was no significant preference for either over-estimation or under-estimation of the stimulus size in errors for each of the three age groups, cannot be rejected. Errors of judgment (scoring $\frac{1}{2}$) were distributed fairly equally on either side of each correct match to the given test stimulus.

A reliability coefficient (Pearson's product moment - 'r') obtained between scores for the two forms of each figure (cards a and b for each basic shape - horizontal and /

and vertical diminishing) was .73, with a standard error of .034. This leaves the correlation significant beyond the .01 level for a sample of this size. Although generally speaking, reliability coefficients are expected to fall between .8 and .98, the obtained coefficient is fairly high when one considers the age range of the subjects where high reliability of a test cannot be expected.

Analysis of the total correct scores for each basic shape showed that the circle and ellipses had the highest score, followed by the square and rectangles. The triangles came next, and the crosses were last with the highest error score. These differences, however, were not significant.

Discussion:

A comparison between these results and those from the previous test, shows that the correlations between age and score are very similar. It is probable that the other factors which were supposed to have been operating in the previous test, were also operating on this occasion. Generally however, with increasing age, a development in ability to match forms from a range of similar forms took place.

Similarly, the mean score for each age group is seen to increase from the youngest group upwards. Together /

Together with this increase in accurate matching with age, comes a decrease in the standard deviations for the age groups. This indicates a narrowing of the dispersion of scores on either side of the mean with age. Therefore, not only is there a general improvement in accuracy of matching with age, but there is also a tendency for the scores to become more homogeneous. For example, in the three year old group about 68% of the scores should fall between 27.25 and 5.49 ($\pm 1\sigma$), whereas for the four year olds, 68% of their scores should fall between 29.36 and 16.32. It can be seen that the variation in scores for the younger age group is much greater than that for the older children. This probably indicates a gradual levelling off of this similar-form matching ability by the age of five years, but is also partly due to a more stabilised application and attention to the task at this age.

The increase with age, however, is much greater in this particular test than in the previous one. All the 't' values for the differences between means for the three age groups were significant to a level beyond the levels for the differences in the previous test. Inspection of the distributions of scores for each age group (see Fig.17) shows that the skewed distribution that was characteristic generally of scores over the whole range of age groups in the previous test is really only present in /

in the present test at the five year old level, and that the distribution for the scores of the three year olds approximates to a normal distribution. Thus only the very bright three year old children would be capable of making high scores on the present test, and the average age required for high success in this test is older than that required in the previous test. This is, therefore, a task which requires on average a greater level of maturity than did the previous test. It will be remembered, however, that the items for the present test were chosen specially to investigate more fully the tendency noted in the previous test on certain items viz., the confusion between similar forms (having the same general outline irrespective of differences in height or area) which was greatest for the youngest age group. This tendency, therefore, is borne out in the present test by the much-reduced scores of the youngest children. This task represents a more difficult task comparable to that imposed by only certain items in the preceding test. This accounts for the fact that this four-choice matching situation involving similar forms, is really only completely mastered on average by the age of five years.

The problem, however, of what factors are responsible for this improvement with age in the present matching task, is again raised. Results indicate that the /

the norm for the three year old would be a score of sixteen out of a possible thirty-two, but also that the dispersion of scores around the mean is so large that a range of from five to twenty-seven is required to comprehend the majority of individual scores in this particular age group. But take the case of the hypothetical 'normal three year old'; given this four-choice matching task, out of the thirty-two presentations, the child will accurately match only sixteen of these i.e. will have 50% success. If he performed in this way on a similar test which had been designed to assess visual acuity, it would have to be concluded that the child had poor form sense. Yet the present test was presented at reading distance, and the forms were large and clear enough to overcome most visual deficiency. It should be noted, however, that not only will the 'normal three year old' have the normal maturity of visual system for his age, but also will demonstrate a pattern of matching response which will be characteristic of the majority of the children in his age group. For example, if he was presented with a certain ellipse, he might well match it with one of reduced dimensions. Yet this same 'normal child' has previously shown himself competent in a matching task, when the forms were sufficiently dissimilar. What factor or factors are accounting /

accounting for his present inability? It is possible that his visual system (including a cortical level of discrimination) is not faithfully representing the difference because the shapes are similar and the sizes are not greatly dissimilar, but this is not likely in view of the present conditions of presentation (large visual subtends). A second possibility is that the difference is being recorded, but is not sufficiently great to be attended to by the young child. If this was the case, some form of reinforced trials might give confirmation of it. A third possibility is that random guessing may be characteristic of the performance of a child so young, due to either incomprehension or caprice. His percentage success, however, could not be obtained with a form of random response; correction has been made for chance guessing, and 50% probability is well beyond what would be expected (even without correction) in a four-choice matching situation. On the occasions that he is successful, therefore, the child's success appears to be due to correct discrimination, and this suggests that the critical features of the differences are being attended to on at least some occasions (the highest correct score for the three year olds was made on the first items on each of the eight cards viz. on the four basic shapes themselves, which in two of the cases /

cases (circle and square) was really a different basic shape from the other three derived shapes; these differences for each size of representation of the items, however, were not significantly different).

Again, therefore, there is left the fourth possibility viz. that the child's understanding of what is meant by 'just like' at age three, is not sufficiently developed always to restrict a subsequent choice to a figure which is exactly like the given test figure. This confusion could occur either at a verbal level in which case the child might not know which one he has to choose, or at the visual level when he examines both and categorises both as having the 'same' quality of, for example, roundness, so that 'just like' which he does understand could then be applied equally validly in his eyes to either stimulus. However, whatever process was occurring, it was followed by an exact match on a number of occasions which precluded the sole operation of chance.

Whether the child does or does not understand precisely what is required of him on all occasions, nevertheless it would be wrong to expect more than a 50% success from an average three year old (and he will be representative of the majority of children of the same age). It is also important to remember at this point, that a fairly high reliability was obtained between presentations /

presentations of the figures in a different orientation, so that a given child's performance could be expected to be fairly stable on this test under the conditions that existed. So a safe conclusion can be drawn as to the normal performance on this type of test of children of different ages (three-five years). This is, that with increasing age, the normal child can more successfully perform a matching task when the choice is between four shapes of similar form. This imposes a fairly difficult task on the average three year old who can be expected to achieve no greater than 50% success. The reasons for such performance may be many, but generally they can be attributed with some assurance to factors of variations in attention and a general deficiency in specificity of concepts. The question arises, however, whether small differences in more meaningful objects might be more accurately responded to.

Summary:

1. There was a significant increase with age in accuracy on a four-choice form matching test. The differences between the three, four and five year old levels were great. The test presented considerable difficulty to the very young child who scored on average only 50% success.
2. With increasing age, the spread of the distribution of scores became much narrower. Scores became more homogeneous /

homogeneous as the ceiling for this type of task was approached (probably from about 4.6. - 5.0.).

3. The reason for error scores in the three year old group is not clear. The percentage of correct scores, however, showed that well-above chance discrimination was taking place. Since all items of the test were of the same order of difficulty, the error scores were probably due to factors other than non-discrimination on a visual level. From observations of the children's performance, it seemed that incorrect matches were due rather to fluctuations in attention and a tendency to make a quick judgment without a full inspection of the key card (in contrast to the deliberate scanning and comparisons which were characteristic of the performances of the older children).

4. There was no tendency at different age groups either to underestimate or overestimate the area of the test figures.

5. A fairly high reliability coefficient was obtained between two identical series of items in the test, so that performance on the test was fairly constant.

e) Test 4: Pictorial Form Discrimination - Pairs of Forms

The difficulty encountered by three year old children in the previous geometrical form tasks, (which seemed largely to be one of attention) might have been accounted /

accounted for partly by the abstract nature of the shapes. This difficulty in attending to small differences which was apparent in some cases might be overcome by using pictorial representations of familiar objects. In this event, however, any improvement shown might be due, not so much to a more stable level of attention because of increased interest in the stimuli, as to a more available use of verbalisation as an aid to matching. Again, however, two familiar objects having a small discrepancy between them, might be equated visually because of their high degree of similarity which in this instance might over-ride the small element of dissimilarity. Also, the naming of the objects might in itself exclude the critical feature from a further examination; for example, the labelling of each of two representations thus: "That's a house, and that's a house" might deter the young child from a further inspection which might result in perceiving that one of the houses had no chimney. The present test was an attempt to study this problem.

Description: Five white cards each 5" x 8", were used. On each card a pair of outline drawings was drawn in black ink. Each item in the series differed a little in the degree of complexity of internal detail and in width (to allow for realistic representation) but the height of the pairs was uniform throughout i.e. 2.5". The width /

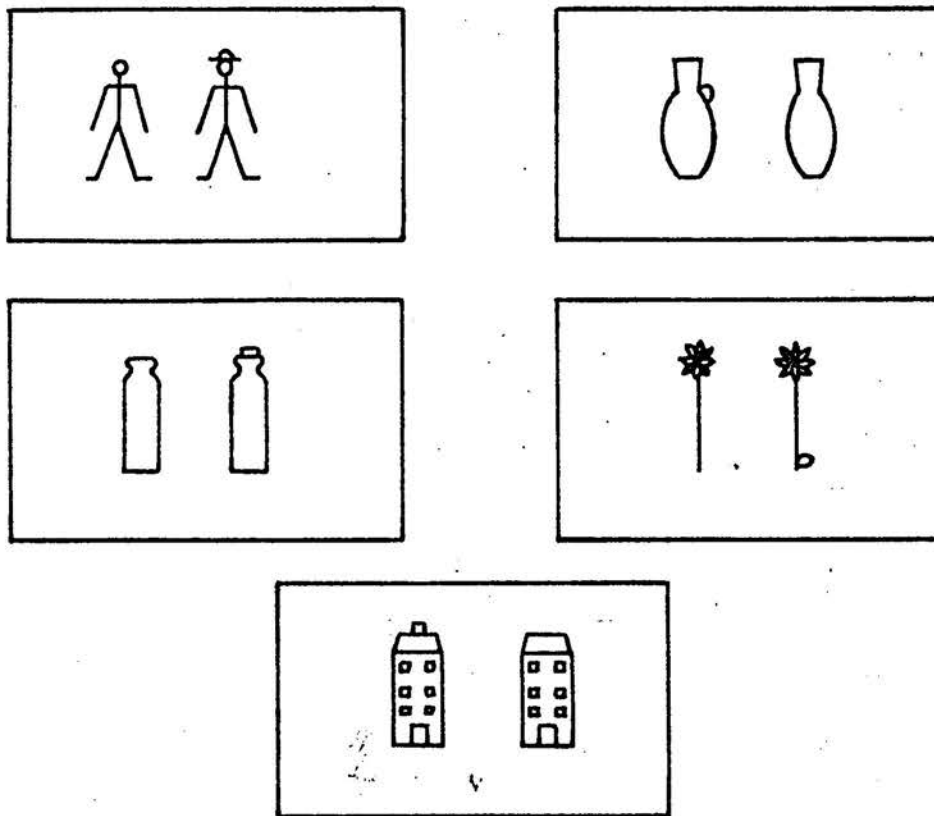


Fig. 18: Test 4 - five key cards.

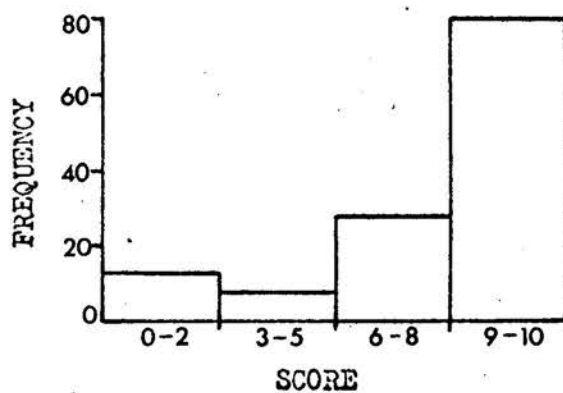


Fig. 19: Frequency distribution of scores (Test 4).

width of the outline was $1/16$ ", and the drawings of each pair were placed 2" apart on the white card. The following objects were represented:

Card 1 : matchstick man without hat; matchstick man with hat.

Card 2 : vase with handle; vase without handle.

Card 3 : bottle without cork; bottle with cork.

Card 4 : flower without leaf; flower with leaf.

Card 5 : house with chimney; house without chimney. (see Fig.18).

As can be seen from Fig.18, each pair differed in one small detail. Throughout the series, this detail was kept as constant as realistic representation would allow (about $3/10$ "). Ten smaller test cards (3" x $1\frac{1}{2}$ ") were prepared with drawings of the ten pictures on the key cards. The presentation of these test cards was randomly ordered.

Subjects: 127 nursery children aged two and a half to five and a half years were tested. These children were drawn from the original group, and each one had previously performed the three preceding tests. The matching procedure required was therefore familiar to them. The age /

age distribution was as follows:-

<u>AGE</u>	<u>FREQUENCY</u>
2.6. - 2.11.	3
3.0. - 3.11.	45
4.0. - 4.11.	68
5.0. - 5.6.	<u>11</u>

N = 127

Table 11 : Age distribution of subjects.

Presentation: Each key card was placed in turn before the child at reading distance and at right angles to the direction of sight. The child was allowed to inspect the card for five seconds after which time E placed the appropriate test card below the key card and said:

"Look at this picture and find me the one just like it."

When S had made his choice and this had been recorded, E asked: "Why is this ... like this one (pointing to the child's match and the test picture respectively), and not like this one (pointing to the remaining picture of the pair)?" The child's response to this question was recorded.

Scoring: S was given a score of one for a correct choice, and a score of half for an incorrect choice which was spontaneously corrected. Chance scoring was corrected for by subtracting the error score from the total number correct/

correct. Thus a score of six out of a possible ten, received a corrected score of two. Scores of five and below received an amended score of zero.

Results: A point-biserial correlation (r_{pbi} - for formula, see Appendix III p.330), between age and correct score (dichotomy was taken as that between successful discrimination - a score of ten, and inadequate discrimination - a score of less than ten), gave a value of 0.27 with a standard error of .08. This value of the ' r_{pbi} ' signifies a small but definite relationship between the two variables, and the standard error can be interpreted as indicating that there would be only one chance in one hundred of a correlation from a sample of the same size deviating more than $(2.58 \times .08) .21$ from the present value. The correlation would still be in the positive region (although very small) at this level. We can therefore say that for 125 degrees of freedom the obtained correlation is significantly different from zero at the .01 level of significance (Wallace-Snedecor tables - see GUILFORD 1956 p.538-539). The null hypothesis viz. that the two variables are not related, can therefore be rejected beyond the .01 level of significance. As to the extent of the relationship, the value indicates that about 7% (r^2) of the scores are positively related to age.

Means /

Means and standard deviations together with their standard errors are given in the following table for each of the three main age groups:-

<u>AGE GROUP</u>	<u>MEAN (M)</u>	<u>ST.ERROR(σ) OF MEAN</u>	<u>STANDARD (σ) DEVIATION</u>	<u>ST.ERROR OF (σ) STANDARD DEV.</u>
3.0. - 3.11.	7	0.49	3.3	0.34
4.0. - 4.11.	8.66	0.32	2.6	0.22
5.0. - 5.6.	8	1.1	3.64	0.77

Table 12 : Means (M), Standard deviations (σ), and Standard errors for three age groups.

The following confidence intervals at the .01 and .05 levels from the means of each age group were calculated from the standard errors:-

<u>AGE GROUP</u>	<u>CONFIDENCE INTERVALS AT .05 level of confidence</u>	<u>CONFIDENCE INTER- VALS AT .01 level of confidence</u>
3.0. - 3.11.	7.96 - 6.04	8.26 - 5.74
4.0. - 4.11.	9.29 - 8.03	9.49 - 7.83
5.0. - 5.6.	10 - 5.83	10 - 4.36

Table 13 : Confidence intervals (.05 and .01 levels) from the Means of three age groups.

Thus all hypothetical means for the age groups differing more than 1.26, 0.83, and 1.1 above or below the respective means could be rejected at the .01 level. Also, all /

all hypothetical standard deviations for the population differing more than ± 0.88 , 0.57 , and 1.99 respectively from the three groups, could be rejected at the same level of confidence i.e., with one chance in one hundred of this occurring.

A 't' test of the difference between the mean scores for the two main age groups yielded a value of 2.87 , which for 111 degrees of freedom, was significant beyond the $.01$ level. The null hypothesis concerning the non-significance of this difference can thus be rejected at the $.01$ level.

A frequency distribution of the scores is given in Fig.19.

An analysis of variance (one-way classification - for formulae see Appendix III p.331) between mean scores for each of the five items gave an 'F' ratio of $.764$ which was not significant. No significant difference, therefore, existed between the five items of the test, although the total number of incorrect responses to each of the items gave the following order of difficulty:- Bottle (21), House (19), Flower (18), Man (14), and Vase (13).

A calculation of the percentage verbalisation of the critical difference between the pairs for each age group, together with the standard errors (σ_p : for formula, see Appendix III p.331), gave the following results:-

AGE /

<u>AGE GROUP</u>	<u>M % VERBAL- :ISATION</u>	<u>STANDARD ERROR of M% (0%)</u>	<u>CONFIDENCE INTERVALS at .01 level</u>
3.0. - 3.11.	29%	6.76	M% +/- 17.44
4.0. - 4.11.	59	5.96	M% +/- 15.38
5.0. - 5.6.	82	11.58	M% +/- 29.88

Table 14 : Mean percentage verbalisation of difference, Standard errors, and Confidence intervals (.01 level) for three age groups

A point-biserial correlation (r_{pbi}) between score (dichotomy was again taken as 10 and -10) and number of verbalisations of the difference between the pairs, was .41 with a standard error of .07, which placed the correlation securely in the fairly substantial positive relationships. The obvious relation which existed between verbalisation and score was thus demonstrated. However, in each age group there was a high percentage of correct responses without any verbalisation of the difference (this, however, does not preclude the possibility that the children in these instances could verbalise the difference):-

<u>AGE GROUP</u>	<u>M% CORRECT RESPONSES WITHOUT VERBALISATION</u>	<u>STANDARD ERROR of M%</u>
3.0. - 3.11	52%	7.45
4.0. - 4.11.	32.6	5.68

Table 15 : Mean percentage correct responses without verbalisation, and Standard errors, for two age groups.

In addition to these results, three children (aged 3.6., 3.6., and 4.3 years) having made an incorrect match then proceeded to give a correct explanation of the difference, and one child (aged 5.1 years) after making a correct match then provided an irrelevant verbalisation. It was also observed that a much greater reluctance to verbalise existed among the younger children, but that they would often do so correctly when sufficiently encouraged. Again, also appeared the tendency mentioned earlier (p.63) to point to both stimuli on the key card with comments like: "That's a house, and that's a house" or "They're both the same." etc.

Discussion: As shown in the results, there was a positive correlation between age and number of correct discriminations, which again points to the general pattern of increased aptitude with age for discrimination tasks. However, when this value is compared with similar correlations in the previous tests, it shows a marked reduction in the relationship. Inspection of the frequency distribution of correct scores, however, would explain this result. It shows that almost half of the three year old group (twenty-one out of forty-five) scored ten on this test and another eleven children in the same age group scored from seven to eight correct. Thus the majority of three year olds scored with well above /

above chance success on this type of pictorial discrimination task. Consequently, from the combined distribution, it would appear that the ceiling for this type of task is reached from about three to four years of age (see Fig.19). After this age, therefore, the relationship tends to break down.

It would seem that the introduction of pictorial material has led to a greater number of correct discriminations in the three year old group than was demonstrated for geometrical forms. It will be recalled that if there was such an improvement, it might have been just as much due to a more available internal verbalisation of the critical difference before the choice, as to the increased and more stable level of attention due to increased interest in the forms. However, it was also thought that in some cases, a labelling of the two key stimuli on first inspection might work in the contrary direction viz., towards uniformity of the stimuli by inclusion in the same concept. Evidence for the latter categorising was again found in the children's spontaneous verbalisations, although the high number of good discriminations tend to suggest that this factor was not too important, and that the visual system in most cases had recorded the difference in spite of this tendency to generalise. This will be discussed later.

The /

The significant difference between the means for the two main age groups, also points to a positive relationship between score and age. Although the majority of the three year olds scored well on this test, the remainder had markedly inferior scores compared with the less-competent four year olds. Also, the dispersion of the scores for the four year old group was narrower than that of the score distribution for the three year olds as indicated by the reduction in the standard deviation for the older group.

The total distribution (see Fig.19) shows a large number of high scores tailing off to a small number of poor scores which is the characteristic pattern for most tests of sensory acuity. It seems therefore that the simpler the task the closer will the results approximate to a visual acuity distribution. It must be remembered however, that this test was carried out at reading distance and only the grossest visual deficiency could have prevented the items from being clearly seen, so it is probable that the children in the low scoring range were responding in this fashion, not because of an inefficient visual system, but because of faulty discrimination demonstrable also at close quarters. It seems more likely that this impaired discrimination was due to characteristic over-generalisation in the young child, rather /

rather than to immaturity in visual development.

The role of verbalisation in this discrimination task will now be returned to. Verbalisation of the difference between each item of the pair after the match had been made, was taken as an indication that the discrimination had been made on a verbal level. (The hypothesis here, however, refers to a type of internal verbalisation. For example, the card with the two matchstick men is presented to the child who inspects it and mentally verbalises: "One man has a hat and the other one hasn't." When a third card is subsequently presented depicting a man without a hat, the child can immediately select the correct match). The question was whether this type of verbalisation (an indication of this having taken place was taken from subsequent ability to verbalise the difference) aided discrimination in any way. It would appear from the results that since the total percentage of verbalised responses increased with age (Table 14) and since score was found to increase with age, these two factors were related in some way viz., that both were increasing with age. But an inspection of Table 15 will show that a high number of children responded correctly in both main age groups without then verbalising the reason for their choice (as was remarked previously, however, this did not /

not necessarily indicate that these children were unable to verbalise in this instance). It is true that many of the children were reluctant to give reasons for their response, particularly among the younger age group, but often did so when encouraged. For want of more information, the results in Table 15 can be taken to indicate only that correct responses and verbalised reasons for these responses were not always related. It seemed possible that a correct discrimination could be made from a purely visual comparison without a verbal analysis of the key stimuli, but generally speaking, these two types of response (i.e. correct discrimination and subsequent verbalisation of the difference) went hand in hand (this topic will be returned to in the next test). The percentage increase with age in the ability to verbalise could be taken as an indication not only of an increased verbal fluency and confidence with age but also of an increase in understanding of the question "Why?" and the relationship involved in this question. The increased percentage of correct discriminations with age might also reflect a more accurate understanding of what is meant by "just like", so that in this way these two factors i.e. score and verbalisation, might be related.

The possibility that a purely "visual" comparison could be made was indicated by a certain type of response. For /

For example, two types of children could be distinguished among those who were unable when asked to verbalise the critical difference between the two key pictures, yet who made above chance successful discriminations. One class of children pointed to the differentiated area, while the other gave no response to the question. It is possible that the first group of children had understood the question, had previously made some verbal comparison between the two, but had been reluctant when asked, to verbalise the difference. By contrast, the other group of children was unable to respond in either way, which tended to indicate that a comparison had been made which was confined to a visual inspection without any active internal verbalisation of the process (this, of course, does not necessarily follow).

That verbalisation on the part of the subjects aided the examiner in assessment of the discrimination is shown by the cases in which an incorrect match occurred followed by a verbalisation which revealed that the critical area of the difference had been seen, and that somehow thereafter the matching procedure had become confused. For example, on one occasion the two pictures on the key card were a man with a hat and a man without a hat. One child inspected these and was then shown a third picture depicting a man with hat. When then asked to find the man /

man just like the one on the third card, the child pointed to the man without the hat. To E's question "Why?", the child replied: "Because he's not got a hat". In this case the area of the difference had clearly been seen, yet for some reason a wrong choice had been made. Some lapse in attention, or inability to maintain the set of the task, or simply confusion, could have accounted for this type of matching error.

Again there was some evidence from observations that a categorising of the two key stimuli was again taking place e.g. "That's a house, and that's a house", especially among the younger children. It is possible that the children were used to being asked to name pictures and thought that on this occasion the same was being required of them. However, the subsequent reluctance of many of these children to make a choice would tend to suggest that this type of categorising reflected an over-riding impression of similarity often at the expense of small differences being attended to.

The effect of degree of understanding of instructions on a response and the effectiveness of the role of verbalisation on matching procedures are difficult problems at this age where great variation in linguistic achievement is often present. At any rate, even if to introduce pictorial material was possibly to introduce another complex variable to the matching response in the form /

form of verbalisation, there can be no doubt that matching performance on this type of task was superior to that on more abstract form-discrimination tasks.

Summary:

1. With increasing age there was an increase in ability to match between pairs of pictorial forms having a small difference between them, although the ceiling for this type of task was achieved earlier than that for previous tests (between three and four years).
2. There was a smaller dispersion of scores about the mean with increasing age, as performance became more stable and more homogeneous for the group.
3. There was an increase with age in the ability to verbalise reasons for a given response.
4. The verbalisation of why the choice was made could be a help towards understanding the choice. It also enabled E to differentiate between a wrong match due to faulty discrimination, and a wrong match due to other causes.
5. The hypothesis that verbalisation (internal) was a tool in good discrimination was difficult to substantiate.
6. The difficulty of differences in linguistic interpretation of instructions given to pre-school children was recognised and discussed.

f) /

f) Test 5 : Form Matching - Pictorial Forms versus Symmetrical Shapes.

The present test was carried out in the hope of providing further information on the role of verbalisation in visual discrimination. Does a readily available ability of a name for an area of difference on first inspecting the two key stimuli help significantly in a later matching situation? (Hypothesis 1) It was also thought, however, that categorising of similar objects might later inhibit the perception of small differences between these objects. Thus, will a readily available category (name) for two objects act so as to impede discrimination? (Hypothesis 2)

Description: The test series consisted of thirty black outline pictures (key cards) pasted on to cardboard (2" x 2"). The dimensions of each picture was approximately $1\frac{1}{2}$ " square, and the outline of the drawings was $\frac{1}{16}$ ". Six standard pictures were systematically altered by removing from them each time, one part from the top, then from the bottom, middle, and side areas, which resulted in a standard and four variations (identical in every respect but one) for each of the six items in the series. Allowing for realistic representation, the size of the missing detail was kept as constant as possible (about $\frac{2}{5}$ "). The series itself was divided into representations of common objects (items /

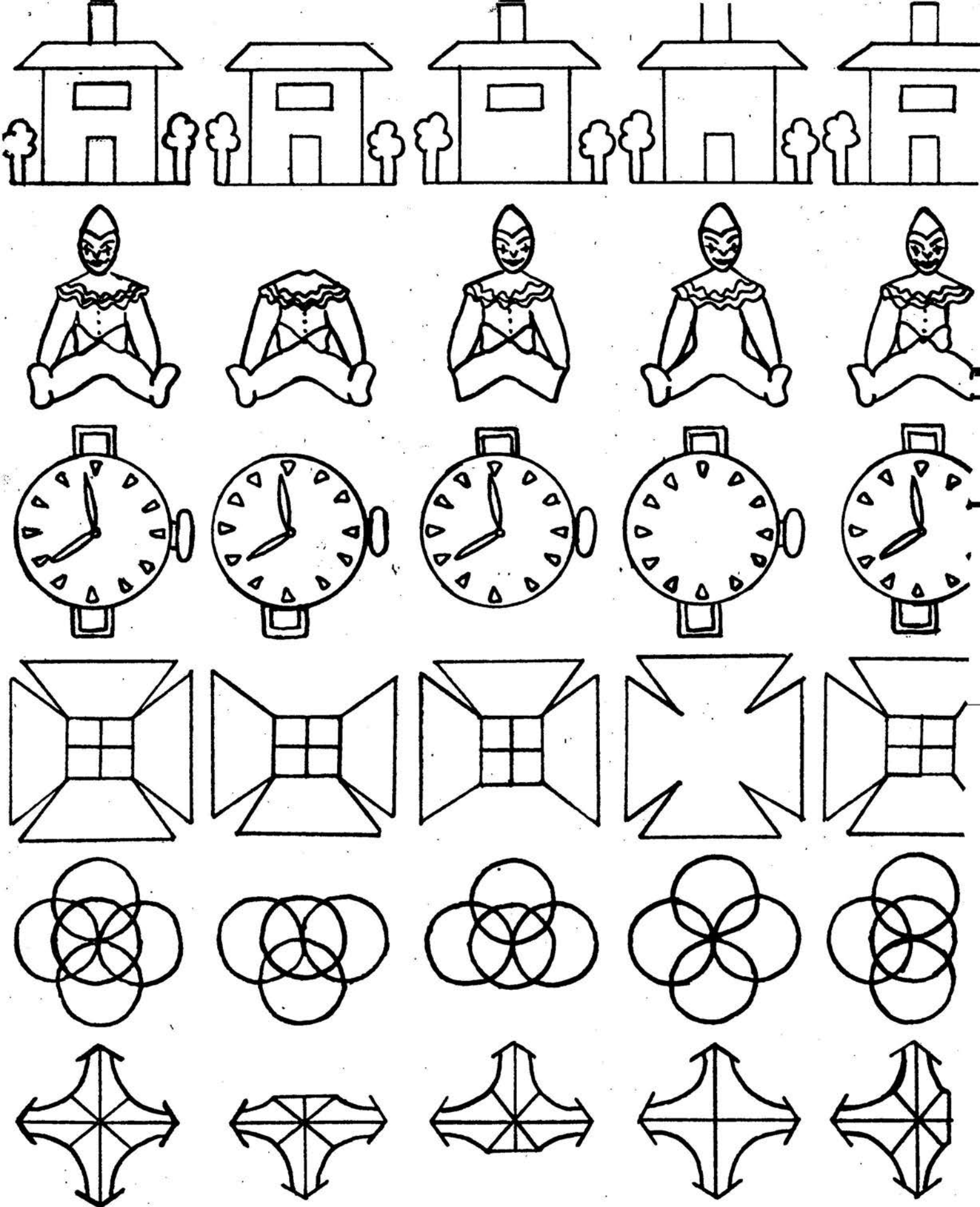


Fig. 20: Test 5 - Standard and Comparison cards of Pictorial Forms (Series I) and Symmetrical Shapes (Series II).

(items one to three - house, clown, and watch), and symmetrical patterns of geometric and topological shapes (items four to six). (See Fig.20 for an illustration of the test). The cards were presented in pairs - each of the comparison cards being presented in turn with the standard. The position of the two key cards (right or left) was randomly varied. A third card (test card) depicting either the standard or the comparison picture was then introduced. The pattern of presentation of the three cards was as follows:-

C = Comparison : (T) = Top Missing; (B) = Bottom Missing; (M) = Middle Missing; (S) = Side Missing

St.= Standard

Series I :

HOUSE : 1.C(T) St. 2.St. C(B) 3.C(M) St. 4.C(S) St.
C(T) C(B) St. C(S)

CLOWN : 1.St. C(T) 2.C(B) St. 3.St. C(M) 4.St. C(S)
C(T) C(B) St. C(S)

WATCH : 1.C(T) St. 2.St. C(B) 3.C(M) St. 4.C(S)
C(T) C(B) St. C(S)

Series II :

CROSSES : 1.C(T) St. 2.St. C(B) 3.C(M) St. 4.C(S) St.
C(T) C(B) St. C(S)

CIRCLES : 1.St. C(T) 2.C(B) St. 3.St. C(M) 4. St. C(S)
C(T) C(B) St. C(S)

CROSSES : 1.C(T) St. 2. St. C(B) 3.C(M) St. 4.C(S) St.
C(T) C(B) St. C(S)

Subjects: Two groups (nine subjects in each group) of nursery /

nursery children were used in this test. All of these eighteen children had previously acted as subjects in the preceding tests, so that they were perfectly familiar with the matching situation. Each child in the two groups was matched as far as possible for age, and ages ranged from 3.1. to 5.2. The distribution of ages was as follows:-

<u>AGE</u>	<u>FREQUENCY</u>
3.1. - 3.6.	2 (1 + 1)
3.7. - 4.0.	4 (2 + 2)
4.1. - 4.6.	4 (2 + 2)
4.7. - 5.0.	6 (3 + 3)
5.1. - 5.6.	<u>2</u> (1 + 1)

N = 18

Table 16 : Age distribution of subjects.

Presentation: The total group was divided to test for a possible practice effect. The first group was given the series in the order Objects - Shapes, while the order of presentation was reversed for the second group. The series of pairs of key cards was presented in turn to the child at reading distance and at right angles to the direction of sight. The child was allowed to inspect each pair for about five seconds, then the appropriate test card (presented according to the above order) was placed /

placed below the key cards, and E said: "Look at this ... and find me the one just like it on these cards (indicating the two key cards)". The child's choice was then recorded, and if he made a correct response, E said: "Why is this ... like this one, and not like this one?" His reply was noted.

Scoring: All correct responses were given a score of one and an incorrect match was rated zero. Again, a spontaneously corrected wrong choice was given half a mark, then the total correct score was corrected for chance guessing by subtracting the error score from it. The responses to the question following a correct match were rated as follows:- V - verbalisation of the difference; P - pointing to the correct area of the difference; and N - a non-response. (Some children, particularly in the older age group, spontaneously verbalised the difference on inspecting the two key cards. This type of response was designated V', and it was significant that such children scored highly on the test. This verbalisation, however, was probably as much an indication of maturity and general awareness as something which later significantly influenced their response.)

Results: A possible practice effect was tested for by adding object score in first presentation to shape score in first presentation (object score + shape score in Group I and Group II respectively), and comparing this result /

result with a score obtained by adding object score and shape score in second presentation (shape score + object score in Group I and Group II respectively). The mean for the first-presented items was eight, and that for items in second-presentation was 8.5. A 't' test carried out between these two means gave a value of .34 which for seventeen degrees of freedom was not significant at the .05 level. Thus, although there was an indication of a slight practice effect, this failed to reach significance.

The effect of age on performance was indicated by a correlation coefficient (Pearson's product moment) of .73. This, with a standard error of .11 was significant beyond the .01 level with sixteen degrees of freedom (see Wallace-Snedecor table - Guilford 1956 p.538). However, a similar correlation between age and number of responses correctly verbalised was .78, which had a standard error of .1. This result was also significant beyond the .01 level. And a third correlation between verbalisation and score gave a coefficient of .78 with a standard error of .1. A multiple correlation (R - see Appendix III for all the formulae) was then carried out on this data, with the score being regarded as the dependent variable (X_1) and age and verbalisation (X_2 and X_3 respectively) representing the two independent variables. (For a full explanation of the processes involved in a multiple correlation /

correlation, see Guilford 1956 p.393-400.) The resulting ' R^2 ' was .62, which gave an ' R ' of .78. This multiple ' R ' represented the maximum correlation between the dependent variable (score) and a weighted combination of the independent variables (age and verbalisation). The standard error of ' R ' was .1, from which it can be concluded that there is one chance in one hundred of this correlation being more than .26 ($2.58 \times \sigma_r$) away from the population value of ' R '. It is therefore highly likely that a genuine multiple correlation of this order exists in the population (for the formula for the standard error of a multiple ' R ' (σ_R) see Appendix III p.331). An estimate of the contribution of each variable to the total variance (i.e. ' R^2 ' which equals .62 = 62%) is given by the product of the β coefficient and the corresponding raw ' r '. Thus,

$\beta_{12} r_{12} = .31 \times .73 = .23 = 23\%$. This product indicates that the age variable was accounting for only 23% of the variance, whereas a similar product of the β coefficient and the raw ' r ' between score and verbalisation ($\beta_{13} r_{13} = .54 \times .78 = .42 = 42\%$), gave a value of 42% indicating that verbalisation as an independent variable was accounting for 42% of the variance.

In order to find support for Hypothesis 1, viz. that verbalisation of a difference subsequently aids matching /

matching for this difference, it was first decided to find the total % verbalisation for each series (object and shapes), and then to calculate the standard error of the difference between these percentages (σ_{dp} - for formula, see Appendix III p.332). The following table gives the % verbalisation for the two series and the standard errors of these percentages (σ_p = for formula, see Appendix III p.331).

	OBJECT SERIES	SHAPE SERIES
% Verb.	39	3
σ_p	11.5	4.02

Table 17 : Percentage verbalisation, and Standard errors, for the two series.

The standard error of the difference between these two percentages was 3.35 which is significant beyond the .01 level (a ' \bar{z} ' value of 2.58 is significant at the .01 level - for a definition of ' \bar{z} ' and its distribution, see Guilford 1956 p.185). Thereafter, the object score and the shape score ~~were~~ separately treated, and multiple correlations were carried out on each set of scores. In both correlations, the scores were again the dependent variables, and age and verbalisation were the independent variables. The correlation coefficient between object score and age was .76 with a standard error of .1. This value /

value with sixteen degrees of freedom was significant beyond the .01 level. The correlation between age and number of verbalised responses was .8, which with a standard error of .09 and sixteen degrees of freedom was significant beyond the .01 level. The third coefficient between verbalisation and object score was .85 and the standard error was .07, giving a significance again beyond the .01 level. A multiple correlation between all three variables gave an ' R^2 ' of .69, and an ' R ' of .83 which in turn had a standard error of .08. The products of the two coefficients and the corresponding raw ' r 's were as follows:-

$$\begin{aligned}\beta_{12} r_{12} &= .06 \times .7 = .04 = 4\% \\ \beta_{13} r_{13} &= .81 \times .85 = .68 = 68\%.\end{aligned}$$

This indicates that verbalisation was accounting for 68% of the variance (R^2) as against age accounting for only 4%.

A similar multiple correlation carried out between the shape score (dependent variable) and the two independent variables age and verbalisation, gave the following correlation coefficients:-

' r ' age and shape score = .69, standard error = .14, $p = >.01$;

' r ' age and verbalisation = .32, standard error = .24, $p = <.05$;

' r ' shape score and verbalisation = .43, standard error = .21, $p = <.05$.

A multiple correlation between these correlations yielded an ' R^2 ' of .52, which gave an ' R ' of .72. The standard error of this value of ' R ' was .1. The resulting products of the β coefficients and the corresponding raw ' r 's' gave the following results:-

$$\beta_{12} r_{12} = .61 \times .69 = .42 = 42\%$$

$$\beta_{13} r_{13} = .23 \times .43 = .1 = 10\%$$

Of the variance in the correlations involving the shape scores, age was now accounting for 42% and verbalisation accounted for only 10%.

For Hypothesis 2, viz. that labelling impedes further discrimination, the mean scores for the objects and the shapes were calculated separately and compared by means of a ' t ' test as follows:-

	<u>MEAN</u>	<u>t</u>	<u>DEGREES OF FREEDOM</u>	<u>p (1-tailed) test</u>
SHAPES	8.7	.629	17	<.05
OBJECTS	7.8			

Table 18 : t tests and significance levels between Mean scores for Object and Shape series.

The null hypothesis viz. that both series were of comparable difficulty, cannot be rejected at the .05 level of probability.

A one-way Analysis of Variance was carried out between the means of the scores for the items whose critical areas for discrimination were in each of the four /

four positions. The 'F' ratio was .58, which with three and seventeen degrees of freedom did not achieve significance at the .05 level.

Discussion: Although there was a slight practice effect evident in the comparison of the means of first presentation scores and second presentation scores in the two groups, this difference failed to achieve significance at the .05 level. It is possible that with a larger sample, this tendency might have been increased, but the lack of significant difference between the means in the present sample permitted the two groups to be considered as homogeneous. In all subsequent results, therefore, the two groups were regarded as one with N equal to 18.

The effect of age on performance of this task was assessed by using a multiple correlation when it was discovered that not only age but also verbalisation was related to score and in addition that these two independent variables were also highly correlated. As a result, it was found that the age variable in fact was accounting for 23% of the total variance as opposed to the 42% accounted for by verbalisation. It would appear therefore, that the apparently high correlation between age and performance on this test is due, not so much to a positive relationship between the two, as to their mutual correspondence with the ability to verbalise the critical difference between /

between the two key stimuli (which in turn is a function not only of age but also, probably of intelligence). The sample is certainly small but the standard error of the multiple correlation was .1 which gave a sufficiently high reliability for 'R'. The population 'R' could hardly deviate from this value of the sample by more than .26 (i.e. at the .01 level : $.1 \times 2.58$).

Hypothesis 1 viz. that verbalisation of a difference subsequently aids matching, depends on the same inference as was made in the previous test viz. that a readily verbalised difference between the two key stimuli (or of the critical feature of similarity between the test picture and the correct match) after a correct match, is indicative of a previously made type of 'internal verbalisation' on first inspecting the key card. The null hypothesis was tested on the basis of this inference. From the first multiple correlation, it was discovered that verbalisation accounted for a greater percentage of the variance than did age. Also, when the percentage of verbalised responses for the object series was compared with that for the shape series, the standard error of the difference between the two was 3.35 which was significant beyond the .01 level of probability. Verbalisation on the object series was therefore significantly greater than that for shapes. Indeed the test was designed with this difference /

difference in mind, although it was thought that a possibility for verbalisation in the shape series might lie in a statement of the position of the difference, e.g., "Top missing" etc. It is true however, that verbalisation would more likely be occasioned by a familiar object e.g., "Roof missing; head missing etc." Because of this significant difference, therefore, it was decided to treat the two series separately. On each of these series, multiple correlations were carried out in order to discover the weight of age and verbalisation in determining the obtained scores on each series. It was found on the object series that 4% of the variance was accounted for by the age variable and that 68% was due to the verbalisation variable. Verbalisation, therefore in this instance was the better predictor of the object score. Again, it is possible, however, that verbalisation of the difference and subsequent matching ability could both be a manifestation of the same ability viz. general awareness, intelligence, etc.

An analysis of the variance in the shape series, however, showed that 42% of the variance was contributed by the age variable as opposed to 10% contributed by verbalisation. The positions of the effectiveness in prediction of the two variables were now reversed. In the discrimination of the shapes, verbalisation was no longer /

longer the better predictor - age was by far the more important independent variable. A ' \bar{z} ' test for a difference between uncorrelated proportions in samples of equal size (for formula, see Appendix III p.332), was carried out between the percentages of verbalisation accounting for the variance in each of the two series, and it was found to be 3.5. A value of ' \bar{z} ' of this size is significant beyond the .01 level, so that the null hypothesis viz. that verbalisation did not affect later matching differently in the two situations, can be rejected beyond the .01 level of probability.

Verbalisation was certainly highly related to object score, but in this case it was thought that verbalisation was more accessible for the object series.

When the child was unable to verbalise, as was probably the case with the shape series, then age became the more important variable. When children can verbalise readily about a difference, there seems no doubt that their ability to do so is largely a predictor of their matching score. That verbalisation is not a necessary part of the discrimination procedure, however, is seen from the low prediction of shape score from verbalisation. In this case, verbalising the difference will be less likely because of the more abstract nature of the stimuli, and the initial comparison between the two key stimuli /

stimuli will be more likely to be mainly a visual one. It is also highly likely that verbalisation is itself an indicator of the same sort of ability that permits accurate matching, so that it is possible that verbalisation is important as a predictor, not because it affects the subsequent match, but rather because it is indicative of the general ability which will be used in the matching procedure.

In hypothesis 2, i.e., that categorization impedes discrimination, categorizing refers to a labelling by the child of the two key pictures on first inspecting them. It was observed that five of the subjects when shown the object series, made comments of the form: "That's a house, and that's a house" etc. It was recognised that this type of naming response is often expected of children of this age in an assessment by parents and teachers of the child's vocabulary. It is possible that the subjects thought this type of response was necessary on this occasion, but also that this identification of the pictures by a common name acted in such a way as to minimise the critical difference between the pictures. In order to test this supposition, it was decided to compare mean scores for the object series and the shape series, the latter of which elicited no spontaneous responses of the kind noted above. If the shape series scores were significantly /

significantly greater than the scores from the object series, such a trend might be indicated. It had to be noted, however, that the shape series tended on the whole to be less complex than the object series, perhaps thus having a facilitating effect on visual discrimination. A 't' test between the two means, however, proved non-significant at the .05 level (Table 18), so that the null hypothesis could not be rejected with any confidence. The difference between the mean scores, however, was in the predicted direction (8.7 - shape series, 7.8 - object series). It is also true that the size of the sample was rather small for a significant difference to emerge, and also that the shape series appeared to be simpler as a discrimination task than that presented by the object series so that the difference could solely be accounted for by this aspect of their difference alone. The shapes were simpler, more symmetrical, highly redundant figures, compared with the object representations. No substantiation, therefore, was found for the categorization hypothesis, although a slight tendency in the predicted direction was noted.

It was also thought that some areas of the picture rather than others might facilitate discrimination by being more likely to command the child's attention.

An /

An analysis of variance (one-way) of the four critical positions, gave an 'F' ratio which was not significant at the .05 level. The sample, however, was small, and a trend might require a larger sample to show itself to a significant degree. It was noted that the mean score for the top position discriminations was five as compared with a mean score of 4.4 for the middle and side positions. This slight indication of superiority of the top positions is in keeping with those findings which demonstrated up-down scanning in children (see p.32).

Summary:

1. No significant practice effect was found in two series of pictorial test items given to eighteen pre-school children.
2. A high positive correlation between age and total score was obtained, but it was found by using the multiple correlation method that this effect of age on score was not as great as that of verbalisation and that the latter was the better predictor of score.
3. There was some substantiation of the role of verbalisation in the efficiency of later matching responses, but it was found that when the nature of the key stimuli were not such as to favour a verbalisation of their point of difference, comparable matching efficiency could still take place. It was supposed in this case that
a /

a more visual comparison of the two items in the pair was taking place. When verbalisation was possible as in the object series, this became the better predictor of score over age, but the positions were reversed when verbalisation was no longer possible. The inability to make verbalisations about the points of similarity and difference between two pictures, in no way affected the ability to make visual discriminations.

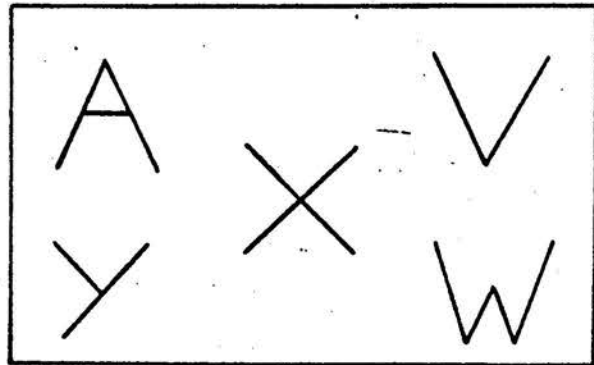
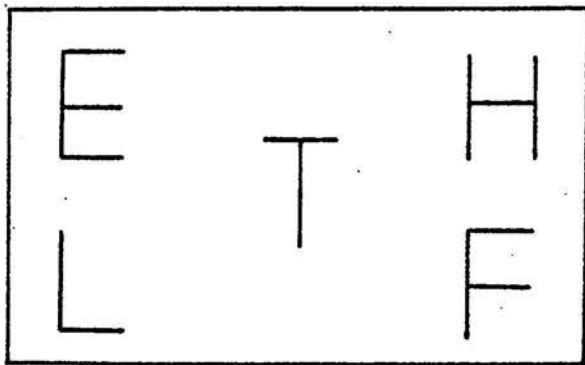
4. There was little evidence that a tendency to give identical names to two pictures differing in one small respect acted towards a later non-discrimination of this difference.

5. There was no significant indication that scanning preferences were influencing better discriminations in certain areas of the pictures than in others.

g) Test 6 : Letter Matching - Vertical-Horizontal and Diagonal Orientations.

Introduction: There was an indication from previous tests, that the younger the child the greater was the tendency to confuse like forms in the matching-from-sample situation. Is this tendency also found in letter discrimination? A visual acuity test (SHERIDAN 1960) (see Fig.56 Appendix II p.316) uses a discrimination task of this sort. In this test, as the children are too young to name the letters shown, they are required to match them individually against a key card on which all /

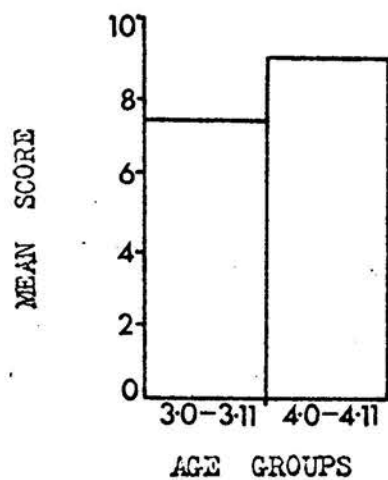
all the letters are grouped. Experience with this test on a group of twenty nursery children (McDERMOTT, undergraduate thesis 1965) indicated a tendency among younger children to confuse the more similar letters e.g. T and H, and V and X. This confusion was understandable in view of the similar orientations of the letter elements; but it became necessary to discover just how general this tendency was under controlled conditions. (It would seem that if this tendency to confuse like forms was a general characteristic of the near perception (or of the near matching-response) of the young child, its presence in a distance acuity situation would be amplified because of the indistinct nature of the smallest letters on the acuity chart. If then, near vision should show this quality of generalisation of the stimulus, then it would be likely that the introduction of the new variable - distance - would emphasise this characteristic because of the less distinct elements of the letters.) Orientation may therefore be the dominant cue in discrimination, and be even stronger when distance is introduced as a further variable. Is this tendency which was first noticed in distance acuity testing, then, borne out in near vision testing, in such a situation as in this particular case, where resolving power was no longer the most important factor in a correct response? How far, then, can a visual acuity test such as Sheridan's be said to measure the resolving power of the eye, or how far is it rather a measure /



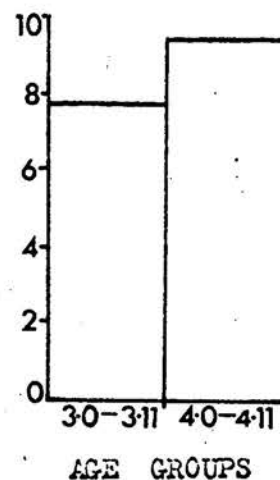
SERIES I: VERTICAL - HORIZONTAL KEY CARD

SERIES II: DIAGONAL KEY CARD

Fig. 21: Test 6 - two key cards in Letter-Matching task.



SERIES I



SERIES II

Fig. 22: Frequency distribution of scores for each age group (Test 6).

measure of a developmental ability to discriminate like-forms as demonstrated in a matching situation?

Description: The test consisted of two sets of black letters (five letters in each set) drawn in black ink on two white cards (5" x 8"). In each set, were those letters with vertical-horizontal orientation, and those with diagonal orientation respectively. Each letter in both sets was inscribed in a 1" square, and the lines of each were $\frac{1}{16}$ ". The arrangement of the letters on each card was as shown in Fig.21. Each key card had a corresponding set of five test cards each 2" square, and with the test letters inscribed, as above, in a 1" square.

Subjects: 127 nursery-school children acted as subjects. These children were included in previous perceptual matching tasks so that the matching response was a familiar procedure to them. The age distribution was as follows:-

<u>AGE</u>	<u>FREQUENCY</u>
2.6. - 2.11	3
3.0. - 3.11.	45
4.0. - 4.11.	68
5.0. - 5.6.	<u>11</u>

N = 127

Table 19 : Age distribution of subjects.

Presentation /

Presentation: Each key card was placed in turn before the child at reading distance and facing him. The five test cards corresponding to the letters on each of the key cards were then placed in turn below the appropriate key card in the following order:-

Set 1 : T, L, E, H, and F; and

Set 2 : V, X, W, A, and Y.

These orders of presentation were determined randomly. When the first key card was introduced, the child was allowed to inspect it for about ten seconds. The first of the test cards was then placed below the key card and E said: "Look at this letter, and find me the one just like it on the big card (pointing to the test card and the key card in turn)." The child's responses were noted, together with any incorrect choice, and one followed by a spontaneous correction.

Scoring: A correct matching response was given a score of one, while zero rating was given to an incorrect match. An incorrect response which was corrected spontaneously by the child was given a score of half.

Correction of the total score for guessing was made by subtracting one quarter of the error score from the number of correct responses.

Results: Correlation coefficients (Pearson's product moment) between age and vertical-horizontal letters and diagonal letters, were .41 and .43 respectively. The standard /

standard errors of these coefficients were both .07, with a probability beyond the .01 level against the population coefficients being zero.

The distribution of scores for each series with age is given in Fig.22.

Means and standard deviations are given in the following table for the two main age groups, together with the standard errors of the two sets of means and the standard error of the difference between each set of mean with its corresponding ' \bar{z} ' value:-

	<u>AGE GROUPS</u>	<u>MEAN</u>	<u>STANDARD DEVIATION</u>	<u>STANDARD ERROR OF MEAN</u>	<u>STANDARD ERROR OF DIFFERENCE BETWEEN MEANS</u>	<u>\bar{z}</u>
SET 1: (Vert.- Horiz.)	3.0. - 3.11.	7.57	2.8	.25		
	4.0. - 4.11.	9.2	1.5	.13	.28	5.8
SET 2: (Diag- :onal)	3.0. - 3.11.	7.75	2.9	.26		
	4.0. - 4.11.	9.4	1.3	.12	.28	5.9

Table 20 : Means (M), Standard deviations (σ), and Standard errors of the difference between Means (σ_{D_M}) of two age groups, for both sets of letters.

Correlation coefficients between the scores for the two sets of letters for the three year old and four year old groups were .77 and .53 respectively. The standard errors for each of these coefficients were .06 and .09.

Both /

Both of these values with forty-three and sixty-six degrees of freedom respectively were significant beyond the .01 level of probability (Guilford 1956, Table D p.539). A 'z' test of the difference between correlation coefficients (for formula, see Appendix III p.332), gave a value of 2.2 which is significant beyond the .05 level (Fisher 'z' coefficient from a Pearson 'r' - Table H, Guilford 1956).

A one-way analysis of variance was carried out between means of scores for each letter in each of the sets. The means and 'F' ratio for each of the vertical-horizontal letters were as follows:-

	T	L	E	H	F
					$F = 10.7; p = \gg .01$
MEANS:-	.96	.92	.74	.92	.85

Table 21 : Mean scores on five letters (Set 1), and corresponding F ratio.

The 't' tests following this significant value of 'F' gave the following results:-

<u>PAIRS OF MEANS</u>	<u>t</u>	<u>p(1-tailed test)</u>
T and E	5.5	$\gg .01$
T and F	3.6	$> .01$
E and F	2.75	$> .01$
L and E	4.09	$\gg .01$
H and F	1.8	$< .05$
T and H	1.4	$< .05$

Table 22 : t tests between Means of five letters (Set 1).

Similarly /

Similarly, a one-way analysis of variance between the mean scores for each of the diagonal letters gave the following results:-

V X W A Y

$F = 5.5; p = >.01$

MEANS:- .79 .94 .90 .93 .93

Table 23 : Mean scores on five letters (Set 2),
and corresponding F ratio.

The 't' tests following the significant value of 'F' were as follows:- 't' between V and W was 2.75 which was significant beyond the .01 level. Therefore, all differences between V and the other three letters were all significant beyond the .01 level. The other four letters gave 't' values which failed to reach significance at the .05 level.

The relation of number of spontaneous corrections to error score is shown in the following table:-

	T	L	E	H	F	V	X	W	A	Y
Total Error Score	5	10	33	10	18	27	7	13	9	9
Total No. of Spont. Correct.	5	1	12	3	0	11	0	3	1	4

Table 24 : Relation of number of spontaneous
corrections to error score on total
series.

A Spearman rank difference correlation (r_s - for
formula, see Appendix III p. 332) between the total error
score /

score and the total number of spontaneous corrections for each of the ten letters, gave a value of .33 which failed to reach significance at the .05 level (Table L p.549, Guilford 1956).

The percentages of each match for each test letter are given in the following table:-

<u>TEST LETTER</u>	<u>% CHOICES FOR EACH LETTER</u>
T	T = 96.1%; F = 1.6%; L = 1.6%.
L	L = 92.1%; F = 4%; T = 2.3%; H = 1.6%; E = 0.8%.
E	E = 74%; F = 20.4%; H = 4%; L = 0.8%.
H	H = 92.1%; L = 2.3%; E = 2.3%; T = 1.6%.
F	F = 85.8%; E = 5.5%; H = 4.7%; L = 1.6% T = 1.6%.
V	V = 78.7%; A = 7.8%; W = 5.5%; Y = 5.5%; X = 1.6%.
X	X = 94.5%; Y = 2.3%; A = 1.6%; V = 0.8%.
W	W = 89.8%; X = 4.7%; V = 1.6%; A = 1.6%; Y = 1.6%.
A	A = 92.9%; W = 4%; X = 1.6%.
Y	Y = 92.9%; X = 4%; V = 0.8%; A = 0.8%.

Table 25 : Percentages of each match made to test letters in the total series.

Discussion /

Discussion: There is a significant increase with age in the score for each set of letters. The standard errors for both coefficients is .07 which means that there is one chance in one hundred of a sample correlation falling as low as .23 in the vertical-horizontal set, and .25 in the diagonal letters. These sample correlations, therefore, are securely placed in significant regions of a positive relationship. Nevertheless, the sample correlations are sufficiently low to make it necessary to enquire into the other sources of variance. It is likely that at this age level, where the stage of sensory development is thought to be a good indication of general mental ability, the other main variance in the correlation coefficients between chronological age and letter discrimination score is likely to be general mental ability or intelligence. Thus, it seems likely that the young bright child will be as likely to score as highly on this type of discrimination test as the older duller child, but in order to pass the criterion both types of child need function about one year older and younger respectively than their chronological age. If, for example, the majority of children can successfully perform this type of task by the age of four years, then the average three year old whose mental development is keeping pace with his age will probably not score highly on such a test (though his performance will not likely be /

be an all-or-nothing response). The average three and a half year old will be likely to pass more items but probably not all, whereas the average four year old should be successful over all the items. At this age, we have almost reached the ceiling for this type of test, so that any increase in age after four years will no longer be reflected in an increasing score which has already reached its maximum. However, the bright three year old (defined as that child whose performance exceeds the average for his chronological age level) may already have reached the ceiling of his performance, whereas the dull four and a half to five year old may now only be fully achieving this level of ability six months to one year after the 'average' child. This type of anomaly probably accounts for much of the variance in the correlation coefficients between age and discrimination scores.

As can be seen from the distribution of scores with age (Fig.22), there is an increase in percentage passing in letter matching tasks from age 3.0. to 5.6. But this increase is relatively slight, for the majority of 3.0.-3.6. year olds (71.4% ; $\sigma_{D_p} = 9.8$) are already able to score four or five of the five items correctly. However, if one takes complete success as criterion, the shape of the curve becomes steeper. There is still a percentage increase with age, but this is not more noticeable and the majority of children are not reaching this criterion until 4.0. /

4.0. - 4.6 years (62.5%; $\sigma_p = 7.6$). The ceiling for this task is therefore, as supposed, about four years on the average. Only the bright three year olds will perform the task wholly accurately, and the more average three year old, will be capable only of performing the task with fair success (scoring four out of a possible five on the vertical-horizontal letter-set). The position for the diagonally oriented letters is somewhat similar. The majority of three year olds (71.4%; $\sigma_p = 9.8$) can score four or five items correctly, but it is only at age four on the average that the majority of children will score perfectly (70%; $\sigma_p = 7.2$).

A comparison of the means of scores on the two sets for the two main age groups (3.0. - 3.11. N = 45, and 4.0. - 4.11. N = 68) shows this same difference between years three and four. The difference between the means for the two age groups on set one (vertical-horizontal) is 1.63 and between the means on set two (diagonal) 1.65. The standard error of the difference between the means is .28 for both tests. The null hypothesis in this instance is that there is no really significant difference between three and four year olds in the population i.e. the two samples arose by random sampling from the same population. In test one, ' \bar{z} ' is 5.8. This value tells us how many standard errors of the difference between means ($\sigma_{D.M}$) the obtained difference extends from the mean of the distribution /

distribution (Guilford 1956). The sample is sufficiently large to allow the assumption of a normal distribution of the ' \bar{z} 's', and the obtained ' \bar{z} ' is well beyond the region of extreme ' \bar{z} 's significant at the .01 level (Guilford 1956, Fig.9.6. p.185). The null hypothesis can therefore be rejected beyond the .01 level of probability, and it can be concluded that years three and four do not score similarly on test one. Similarly, the ' \bar{z} ' of 5.9 on test two, leads to the same conclusion. What, then, is the size of the differences? In test one, the difference between the two means is 1.63 with a standard error of the difference of .28. There is therefore one chance in three that any sample in the population would depart more than .28 from the obtained difference. There are five chances in one hundred that a sample of this size would depart more than .55 ($1.96 \times .28$) from the difference, and one chance in one hundred that any sample would deviate more than .72 ($2.58 \times .28$) from the difference. Similarly, in test two there is one chance in one hundred of a deviation of more than .72 from the sample difference. In sum, there is one chance in one hundred of a difference of less than .91 arising between means of any sample of this size in the population on test one, and of a difference of less than .93 arising between means of any sample on test two.

The two sets themselves are positively correlated
in /

in each of the two main age groups. The coefficient of .77 between the two tests in age group 3.0. to 3.11 (N = 45) has a standard error of .06 which places any sample of this size from the population securely in the positive correlations. In age group 4.0. to 4.11., the correlation between the sets of .53 has a standard error of .09, and while these scores are not quite as positively related as the same sets given to the younger children, the relationship is still a significantly positive one. It is interesting to question why the difference took this direction (the 'z' test of differences between 'r's' - for formula see Appendix III p.332, gives a ' \bar{z} ' of 2.2 - for formula see Appendix III p.332, which is significant beyond the .05 level of significance; thus, the difference appears to be a real one). One would expect greater reliability of test-to-test performance in the older age group. It is true that both groups scored more highly on the second test than on the first, but it is possible that with the higher scoring of the four year olds differences in difficulty emerged, whereas the general lower scoring of the three year old group tended to render their scores more homogeneous over the two tests. It is also possible that a practice effect carried from the first set of letters to the second had a differential effect on the two age groups, probably in the direction of a greater practice effect /

effect for the older children. These reasons would account for the significant difference (.05 level) between the correlations for the two age groups.

The 'F' ratios for both sets of letters are highly significant (beyond the .01 level in each set of means). 't' tests following the significant 'F' ratio in test one show that not all means are significantly different. The mean scores for letters T and E are very different; also those for T and F, those for E and F, and those for L and E. Mean scores for H and F are not significantly different, and likewise scores for T and H. T appeared to be the easiest letter in the set ($M = .96$) followed by L and H (both $M = .92$). F was second in difficulty ($M = .85$) and E proved the most difficult letter ($M = .74$). It was also noted that this difficulty with the letter E was reiterated in the number of spontaneous corrections made in matchings from it (viz. twelve). It is also interesting to look at the most frequently incorrect match made from E viz. F with a percentage response of 20.4 ($p = 3.58$). This percentage was split evenly between the two main groups (thirteen F responses to E in each group). The confusion is understandable in view of the great similarity which exists between these two letters, but it is interesting to note that E was not chosen as much in the incorrect F responses (5.5%). It would appear, then, that insufficient /

insufficient scanning on the part of the pre-school children, and a tendency to concentrate on the upper part of the stimulus, was responsible for this first type of error, yet the same principle did not hold when the position of the letters (sample and key stimuli) was reversed.

The results for the diagonal set of letters have a similar pattern to the previous set, though the former appeared to offer less difficulty to the children and much less scope for confusion. The mean score for V differed significantly from the means for the other four letters in the series, though these four other means were similar to each other. V was the most difficult letter to match ($M = .79$), whereas the other letters were relatively simple ($MX = .94$; $MW = .90$; $MA = .93$; and $MX = .93$). Did the incorrect choices for V show a significant preference for any of the four letters? The error scores on this second set generally are reduced, which may have been as a result of practice though it is also likely that it is due to the greater facility of the second test. Yet the percentage choice of A for the test letter V is 7.8% (five children in each of the two main age groups chose A for V). This is somewhat surprising, for A does not seem to be as similar to V as Y does (Y, however, did receive 5.5% of the wrong choices for V). But A appears to be a reversal /

reversal of V and it is certainly true that the young child's lack of discrimination between up-down reversals has been widely attested.* It is interesting to look further at the high-percentage choices of letters in the error responses:-

<u>TEST LETTER</u>	<u>INCORRECT MATCHES with % CHOICES</u>	<u>REMARKS</u>
L	F (4%)	Up-down reversals? (cf. GIBSON 1962, see p.28).
E	F (20.4%)	Attention to top of figure? (cf. KERPELMAN <u>et.al.</u> 1964, see p. 31)
	H (4%)	Dominance of middle area in scanning? (cf. ZINCHENKO <u>et al.</u> in ZAPOROZHETS 1965, see p. 30)
F	E (5.5%)	Attention to top of figure? (as above).
	H (4.7%)	Dominance of middle area? (as above).
V	A (7.8%)	Up-down reversals?
	Y and W (5.5%)	Attention to top of figure?
W	X (4.7%)	Central area and complexity?
A	W (4%)	Up-down reversals?
Y	X (4%)	Attention to top of figure?

Table 26 : High-percentage choices of letters in the error responses to all letters in the series.

Summary: The results suggest that although the majority of /

*NOTE: It will be remembered that Wohlwill & Weiner's study (1964) - see p. 32 , indicated that children were highly successful in differentiating stimuli on the basis of their orientation under those particular experimental conditions. Children, therefore, are not unable to respond to spatial orientation; nevertheless, they often fail to make a differentiating response.

of children were correct in their matchings the remainder showed consistent types of error viz. a tendency to attend to the upper part of the figure with inadequate scanning of the lower half (e.g. E and F), and a tendency to reverse the figure (e.g. V and A). The smaller percentages of incorrect choices were probably due to random pointing or to fluctuations in attention. The more similar the appearance of the letters, the greater will be the resulting confusion, though this will be more marked when the tops of the two letters are identical or where up-down reversals can be made.

h) Test 7 : Part-whole Perception : Naming Response to Composite Pictures.

Introduction: There has been a strong suggestion over the preceding perceptual tests that the younger pre-school child tends to perceive globally i.e., that the overall characteristics of the stimulus dominate perception often to the exclusion of the perceiving of small differences. This tendency was apparent, not only in object perception where it was thought that the categorising of objects might have been responsible for the absence of discrimination, but in the discrimination of letters and abstract figures where it was probable that no such labelling could be taking place. It was also found that above-chance discriminations were nonetheless taking place over the test series which seemed to rule out /

out the child's possible inability to 'see' the small differences. Is this finding, then, a general feature of the perception of the young child, and are detailed parts of a stimulus ignored because the perception of the three year old child is such as to make him concentrate on the whole qualities of the stimulus rather than on its parts?

Material on the development of part-whole perception has been furnished mainly by studies of age changes in the Rorschach responses, and most studies are in agreement that initial unstructured global perception in early childhood gives way to a perception of details in middle-childhood, and eventually in adults to a more integrated perception of the whole (see Review of Literature p.39 for a fuller treatment of this subject). The present study is concerned with two of these earlier findings, those of MEILI-DWORETZKI (1956) and ELKIND et al. (1962, 1964).^{*}

Meili-Dworetzki, though concerned with the genetic analysis of Rorschach responses investigated part-whole perception with figures in which both parts and wholes had independent meanings e.g., one of her drawings had a /

^{*} NOTE: It will be seen that two of the studies mentioned previously in the Review of Literature - Part-Whole Perception - see p. 39, are being repeated in this section. This has been thought to be necessary for the sake of continuity in the present argument.

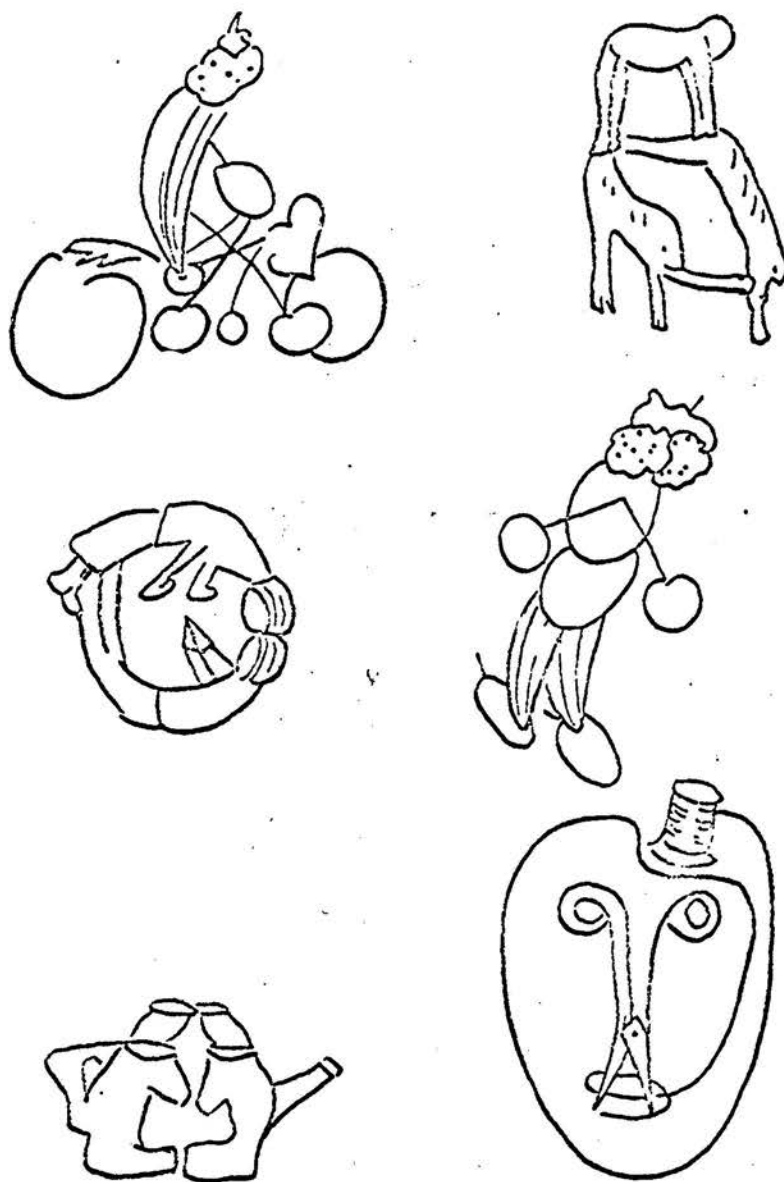


Fig. 23: Six ambiguous figures (Meili-Dworetzki 1956).

a number of fruits drawn, so that in their entirety they resembled the figure of a man (see Fig.23). She found that, for her figures, wholes were perceived at an earlier age than were parts. In 1962 and 1964, Elkind et al., in carrying out studies in order to explore systematically Piaget's theory of the decentring of perception, attempted to explain Dworetzki's findings on her stimulus materials. They claimed that her stimuli favoured 'centring' on wholes rather than on parts. Three main reasons were given for this conclusion:-

- i) parts were often superimposed so that they were not always clearly represented;
 - ii) schematic drawings were used with the exclusion of some common identifying characteristics; and
 - iii) parts were often furnished by unfamiliar objects outwith the experience of the young child.
- Her findings that wholes were perceived at an earlier age than were parts and that there was a regular increase with age in the percentage of subjects who saw both parts and wholes, do not necessarily support Piaget's theory for according to him, whether wholes or parts are perceived is determined by the field effects produced by the stimulus configuration and not by whole or part tendencies in young children. The authors hypothesised that changing some of the features of the stimulus materials /

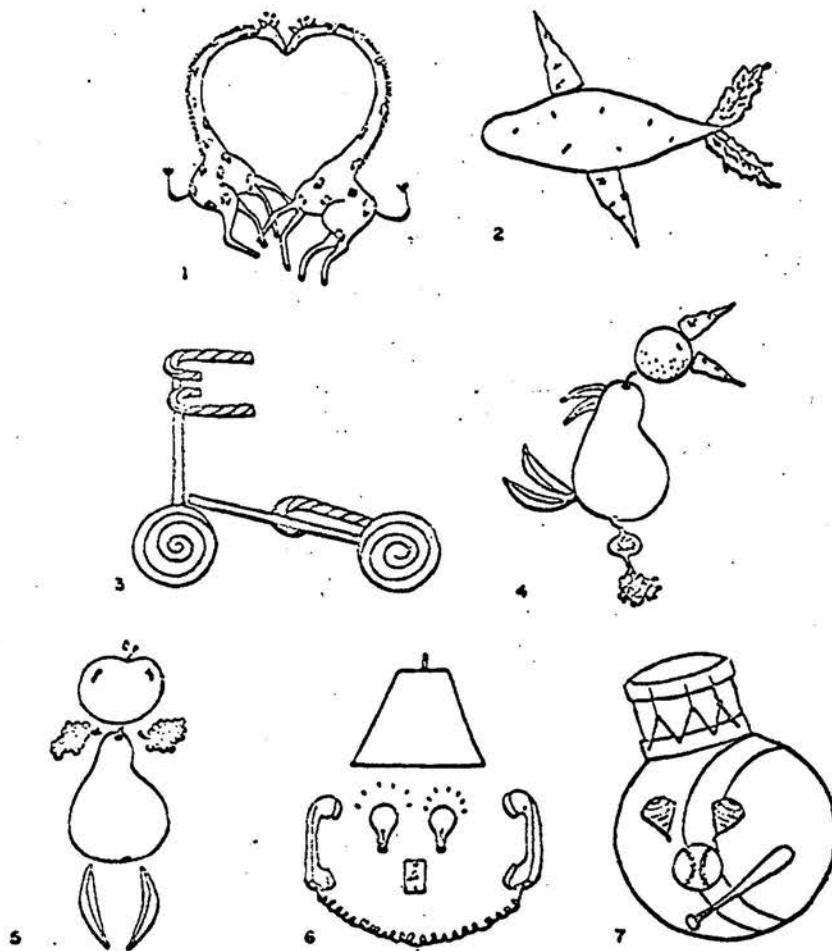


Fig. 24: Drawings used in the study of part-whole perception
(Elkind et al. 1964).

materials, would lead to results consistent with the decentring theory. These authors, then used figures taken from nursery school books, and having previously carried out pilot studies on those parts easier to recognise than the wholes, constructed the P.I.T. (Picture Integration Test). This was pre-tested on groups of nursery children, and the parts were easily recognised by the majority of four and five year olds. These figures were clearly drawn with all identifying characteristics and were not superimposed (see Fig.24). The question was asked: With figures in which the field effects favour part perception, will parts be perceived earlier than wholes? Their results clearly demonstrated the presence in young children of part perception. They concluded that when figures are such that the laws of closure, good form etc., favour the perception of parts, the parts will be perceived at an earlier age than will the wholes. They also concluded that since cultural differences have been found to be negligible, differences between their own and Meili-Dworetzki's findings were due to differences in the stimulus materials and could not be attributed to an inborn tendency to perceive wholes. Meili-Dworetzki's findings are more reasonably ascribed to the fact that her figures favoured the emergence of whole over part perception. The authors /

authors concluded:-

"...It may be that in perception, as in embryology and development generally, growth is sometimes from whole to part and sometimes from part to whole, and that generalisations regarding the sequence of part-whole perception cannot be made without adding some specific information as to the characteristics of the stimuli employed."

It is interesting to note, however, that the earliest age group used by Elkind et al., in order to come to these conclusions is four years six months. This is rather an old (!) age group to use as a basis for the conclusion that there is no inborn tendency to perceive wholes. The present study was an attempt to assess the effect on a younger age group of these stimuli which were designed to favour part perception.

Description: The test series of composite pictures was based on the P.I.T. of Elkind et al. Three of the items from the original test were excluded because of general unfamiliarity of the parts to a pilot group of pre-school children. Two other composite pictures were then designed and added to the remaining four items of the P.I.T. making a total of six figures. The whole figures depicted a scooter, a lady, a face, a man, a duck, a second face. The first face and the man, were not in the original P.I.T. The parts of which these pictures were comprised were first drawn separately on individual cards, and presented to the same pilot group of /

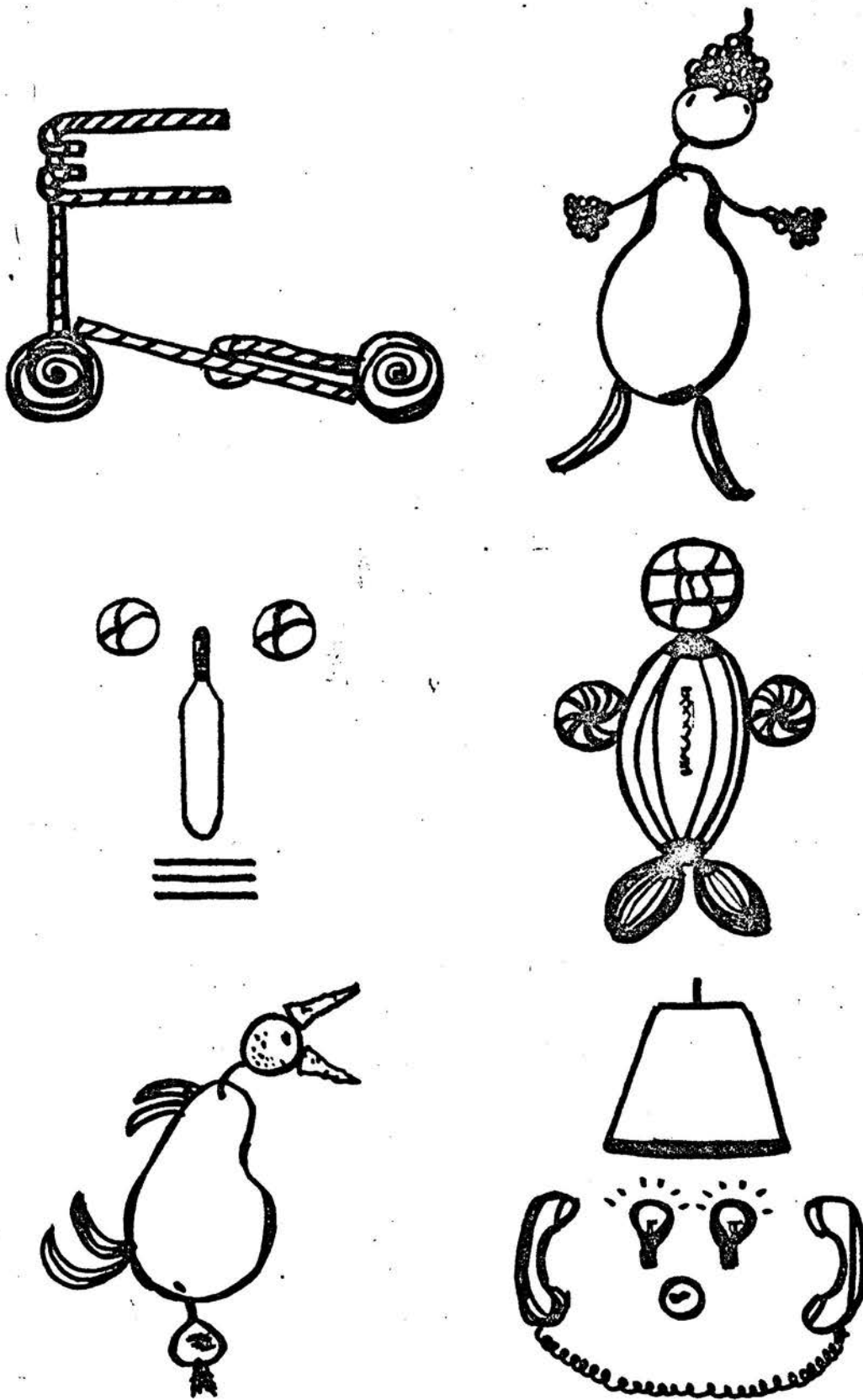


Fig.25: Test 7 - six pictures used in Part-Whole Perception.

of nursery children. All of the parts were easily recognised by the majority of these children. The figures were then drawn in black ink on white cards (5" x 8"), the drawings being roughly $2\frac{1}{2}$ " high and the outline approximately $\frac{1}{16}$ ". The parts were clearly drawn and were not superimposed. The drawings were made as similar as possible to the P.I.T. drawings (see Fig.25). The series, therefore, provided a comparable situation in which, according to Elkind et al., the field effects would favour part perception.

Subjects: 120 nursery school children aged between 2.6. and 5.5. were given the part-whole tests. The age distribution was as follows:-

<u>AGE GROUP</u>	<u>FREQUENCY</u>
2.6. - 2.11.	7
3.0. - 3.5.	16
3.6. - 3.11.	36
4.0. - 4.5.	28
4.6. - 4.11.	24
5.0. - 5.5.	<u>9</u>

N = 120

Table 27 : Age distribution of subjects.

Presentation: Each child was tested separately. As in the instructions for Elkind's test, E said: "I am going to show you some pictures one at a time. I want you /

you to look at them and tell me what you see. What do they look like to you?" The child was then handed each of the six cards in turn and after his first response which was recorded, E said: "Do you see anything else?"

Scoring: A response was scored W when the child used the stimulus as a whole. The response did not require to be entirely accurate but did need to be appropriate. A response was scored D when it was related to the part-stimuli (but not to part of a previously mentioned whole stimulus e.g., 'lady' - W; 'fruit' - D (but not 'legs')). The third category was not really of relevance to the present study, but it formed the basis of an interesting comparison with Elkind's study. A score of W + D was given when the whole was mentioned together with the new part concepts e.g., 'a lady made of fruit'. When part of the whole and a new part-concept was responded to, the category (W + D) was given e.g., 'head'; 'pears and apples' ('head' obviously presupposing the recognition of a whole human figure).

Results: The following table gives the percentages of Part, Whole, Part-Whole, and (Part-Whole) responses given to the composite pictures by each of the six age /

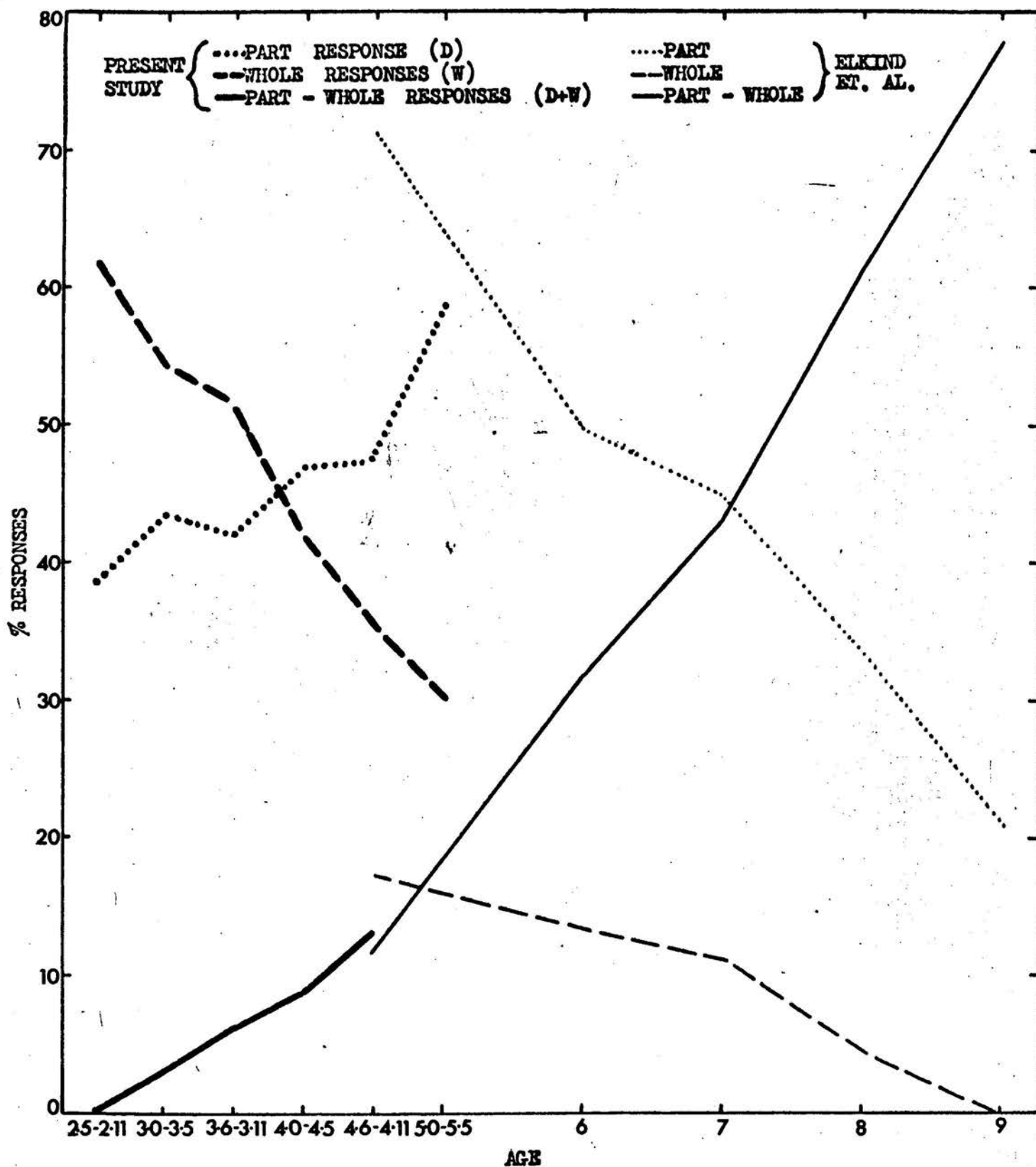


Fig. 26: Graph showing percentages of Whole, Part, and Part-Whole responses obtained in the present study, together with results obtained by Elkind et al. (1964).

age groups:-

<u>AGE GROUPS</u>	N	%W	%D	%W+D	%(W+D)
2.6. - 2.11.	7	61.8%	38.2	0	0
3.0. - 3.5.	16	54	43.4	2.6	0
3.6. - 3.11.	36	51.4	42.5	6.1	0.8
4.0. - 4.5.	28	41.9	46.9	8.8	2.4
4.6. - 4.11.	24	35.8	47.1	13.2	3.9
5.0. - 5.5.	9	30.3	58.9	8.9	1.9

Table 28 : Percentages of Whole, Part, and Part-Whole responses for six age groups.

This table of results is represented in graphical form, together with the results of Elkind et al., in Fig.26.

The standard error of the percentage of W responses in the first three age groups grouped as one (55.8%) was 6.4, and the standard error of the percentage of D responses in the same group was also 6.4 (41.4%). The standard error of the difference between these two average percentages was .088 which gave a ' \bar{z} ' value of 1.7. This value just fails to reach the .05 level of probability, so that although obvious differences in the percentages of these two types of response to the composite pictures do exist in this sample, the difference just fails to reach significance at the .05 level.

Discussion: Although the above standard error of the difference between part and whole percentage-responses in /

in the total age group 2.6. - 3.11. failed to reach significance, it appears from inspection of the graph that certain trends are present, which perhaps might have been amplified by a larger sample.

It is interesting to compare the results with those obtained in the earlier study by Elkind et al., using almost the same set of pictures, but with an older group of children. It will be remembered that these stimuli were designed expressly for the purpose of favouring perception of parts rather than of wholes, the perceived parts being due to the field effects produced by the stimulus-configuration. The set of figures used in the present study were similar to the previous ones in this respect: that on a previous occasion, other children of the same age were able to identify the parts drawn separately on individual cards. With these considerations in mind, it is surprising to find that with the younger age groups, the perception of the stimulus as a whole predominates over the perception of detail (this difference, however, did not quite reach statistical significance). Elkind's group of one hundred children were considerably older than the range of ages in the present study, however, and there is only a small overlap between age groups 4.6. - 5.5. These two studies taken as a whole, therefore, should show a developmental trend in various aspects of /

of part-whole perception from age 2.6. to nine years.

Let us first consider the development of W+D responses (a response involving the whole stimulus with a subsequent perception of parts or vice versa). The correspondence between the two parts of the curve is remarkable. In other words, the developmental trends in part-whole perception or 'decentration' found by Elkind et al., is corroborated by the present study. This takes the form of complete centration in the very young child gradually giving way to a decentration, and finally to a stage when part and whole are both not only perceived, but are perceived and simultaneously attributed to the same perceived form e.g., 'a man made of fruit'.

But this congruity of findings breaks down on a consideration of the other two dimensions represented on the graph viz. the perception of parts and the perception of wholes. Part responses show a relatively low incidence at age 2.6. - 2.11. (about 37% of responses), rising to about 59% by age 5.0. - 5.5. Elkind's values at age 5.0. roughly correspond with the present study, and after this, the part responses show a sharp decline until age nine when about 21% of responses are in this category. There is an indication here of a peak of part responses from about age 4.6. to 5.5. Earlier than this, the percentage of part responses drops, and later responses also show a comparable lowering in the perception of detail /

detail. Elkind's findings, then, which he discusses as indicating that children will perceive parts more readily than they will perceive wholes, when the stimuli are such as to favour part perception, seem only to apply to age 4.6. and a little later. His statement, therefore, that these results demonstrate that there is no inborn tendency to perceive wholes, is based on too few children (twenty-three in age group 4.6.) and on too old an age group. Inspection of the findings in the present study using younger children (again, however, liable to the same criticism of too few subjects) shows that his conclusions are not necessarily valid ones. The predominance of part perception at age five, appears from the combined results (see Fig.26) to be the height of a developmental progress, but there is a building-up from age 2.6. where the responses in this category are relatively low. In other words, where stimuli are such as to favour part perception, the majority of five year olds will indeed perceive the parts, but not so two and three year olds. Are inborn perceptual tendencies perhaps indicated contrary to Elkind's conclusions? The present sample is not sufficiently large to be able to draw valid conclusions as to the perceptual tendencies of the population.

The development of whole responses is also remarkable. The cross-over at about age 3.6. from a greater tendency /

tendency towards whole responses, to a greater tendency towards part responses, is clearly seen on the graph (Fig.26). The low incidence of part perception in the earliest pre-school years is related to a relatively high incidence of whole responses, to stimuli which, it will be remembered, were designed to favour the emergence of part perception. It would appear, therefore, (although from a small group of children) that the perception of the very young child is determined, not by Gestalt-like laws of closure, good form, etc. (where perception of parts or wholes would depend upon the configural character of the stimulus materials), but rather by a tendency to respond to the over-all characteristics of the stimulus, as found in preceding perceptual studies (cf. also, SEGER's Syncretism - see p.39).

Thus, there is the probability that when a composite image is shown to a young child (three year old) and his visual ability is being assessed by his perception of detail within the image, the perception of this child will tend, as dictated by his stage of perceptual development, to be dominated by the over-all characteristics of the picture rather than by the critical parts. A good example of this might be the visual acuity test of RABETGE (1965). If one considers the very similar over-all forms of, for example, the car and the motor-bike (see Fig.62 Appendix II, p.326), the difficulty imposed on /

on the young child by this type of stimuli, viz. pairs of similar forms, will be clear. It must also be remembered that a perceptual tendency such as this, will probably be magnified by the introduction of the distance variable, where the blurred appearance of the very small stimuli will minimise the perception of the small differences in detail. It is probable that if a three year old child was asked to choose from two such key pictures, one of which was being presented at a distance, he might equally choose either, since both meet the requirements of over-all similarity - a criterion which appears to be imposed by the global (or syncretic) nature of the perception of the pre-school child.

1) Test 8 : Simplified Objects : Naming Response.

Introduction: The most popular method of testing the vision of pre-school children, is by means of picture charts. Generally, the child is shown a black and white representation of a common object at a distance of twenty feet and is required to name the object. The obsolete nature of many of the items on these picture charts has been widely criticised and it has been observed that the overcrowded lines tend to confuse the young child. The question now being turned to is the validity of the naming response as an index of visual discrimination /

discrimination. Even under ideal testing conditions such as good rapport between tester and child, and proximity of the task ensuring the presentation of a clear picture to the child, how far can a naming response be regarded as an accurate representation of the resolving capacity of the child's eye? It will be remembered that reference was made previously to the inclusion of naming tasks in certain Intelligence scales, notably the Stanford-Binet Scale (Form L-M, 3rd edition 1960). In this test, Picture Vocabulary is an item which appears at Year II, II-6, III, and IV, where for each age group respectively this item was found to correlate (biserial correlation) with the total score by .69 (1937); .77 (1937) and .61 (1960), .77 (1937) and .64 (1960), and .68 (1937) and .79 (1960). In the 1960 revision, Picture Vocabulary was found to have the highest item validity over the other five tasks at the IV year old level. (It is also noteworthy, that four of the six items at this age are based on visual discriminations; after this age level, the items tend more towards manipulatory and verbal skills.) For this test item, the average three year old child is expected to name ten of the eighteen items in order to pass the criterion for his age group, but this criterion rises to fourteen items for year IV. It is implicit that /

that some children will be unfamiliar with certain objects represented, but it is also recognised that the child's inability to relate a two-dimensional representation (often perhaps at an unfamiliar angle or unusual perspective) to the object it is designed to represent, may also be responsible for his non-response. Also, the child may be familiar with the particular object represented but have forgotten the appropriate name, in which case a response which is in some way associated with the object may be given (for example, a three year old child gave the response 'flowers' to a picture of a watering-can in a popular picture chart - McDERMOTT 1965). The question arises in consequence of this type of associative response: Is one entitled to give the child credit for 'seeing' the object as inferred from his response?

Thus, if pictures from the above-mentioned intelligence scale were used in a visual acuity test (and some of the items do bear a marked resemblance to pictures used in various acuity charts) the average four year old would be expected to name only about fourteen of the eighteen objects represented. And if the four with which he had difficulty were on the lower lines of /

of the chart resulting in a correct naming of items only as far as the $6/9^*$ line, would it be valid to conclude from this that the child's vision was impaired? The question is even more pertinent to the testing of the average three year old child, who would be well within his 'mental rights' to misname or make no response to eight of the eighteen pictures. At this age level, a cognitive task like naming (as with the matching response) will probably be fully acquired only by the brightest three year olds. Only applied to these children, could a test such as this be regarded as a reliable and valid index of form sense. The remainder of the children in this age group will be liable to make errors such as those related to unfamiliarity with the object, inability to relate the picture to a known object, or an associative response in the absence of the correct name. There is another type of error which has been encountered in the testing of young children viz., a generalisation of the stimulus. This might well be related to that feature of the normal perceptual development of the pre-school child found in previous studies where the global nature of the young child's perception /

* NOTE : For an explanation of Snellen notation, see Appendix I, p.279 . It is the convention in the United Kingdom to express the fraction in metres e.g. $6/9$, but it also expressed in feet - $20/30$, or as a decimal fraction - 0.66. For the sake of coherence, all notations in this study have been expressed metrically. This has sometimes involved the conversion of notations used by certain authors, but where this has been done, a note to this effect has been appended.

perception minimised differences. This is probably associated also with the very loose verbal concepts characteristic of this age group. This apparent fact of the dominance of wholes in the perception of the young child, might indeed be related to deficient form sense, if it were not for the fact that the visual system is capable on certain occasions of detecting small differences. The child's acuity appears to be capable of registering the details, but this need not necessarily ensure that the details are being attended to. This question of generalisation of the stimulus is the topic of the present study. A previous study (McDERMOTT 1965) indicated decisively that a type of generalisation did occur. Part of the project was a study of the naming response of a group of pre-school children to a series of pictures used in visual acuity picture charts. In this instance, the pictures were presented close to the children so that they encountered no visual difficulties in looking at the pictures. As a result, the incorrect responses were unrelated to faulty visual discrimination. A correlation coefficient of .47 was obtained between correct score and age (significant beyond the .05 level), and one of .46 was obtained between correct score and mental age. This small but clear relationship indicated that the response was a function of both mental and chronological /

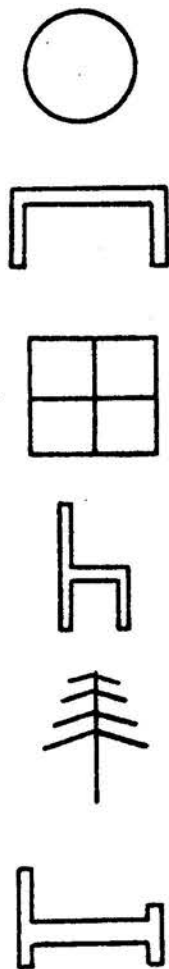
chronological development (both of which would be keeping pace with each other in the average child). Generalisation of the stimulus was responsible for most of the errors in the study although it is also probable that this tendency was aggravated by the difficulty which some children seemed to experience with stylised pictures. GIBSON (1951) pointed out that a drawing was not a simple presentation to sense-organs, but a representation of a 'substitute object'. This secondary quality of pictures is apparent in the difficulties experienced by some young children in understanding and responding to their content. From the examples of generalisations given below, it can be seen that although many of the responses are appropriate and therefore meaningful, it would be difficult to ascribe a correct response to them. It appears that during the process of the gradual refinement of the child's concepts, any stimulus whose shape is at all similar to that of another object, is likely to become confused with that other subject if the latter is more familiar to or has greater value at the time for the child. For example, the stimulus picture of a teddy-bear received four responses of 'baby', a kettle was responded to in twenty-seven cases by 'teapot', and a picture of a row of stylised toy soldiers were called 'milk bottles' by nine children.

Given /

Given this tendency towards generalisation, which factors will encourage it and which will limit its appearance? Simplicity of outline, it would seem, would act in such a way as to encourage a good perceptual response from a young child. On the other hand, however, any simplification of a pictorial representation of an object might lead to ambiguity. The question of ambiguity in simplified forms was considered in the present study. Could drawings be simplified and yet still retain non-ambiguity for the pre-school child? Presumably if some unique characteristic of an object was retained, ambiguity would be minimised, although this need not necessarily be so in the perception of the young child. It also must be emphasised that such an identifying feature would have to be empirically established.

Description: The test consisted of twelve simplified line drawings of common objects each drawn in black ink on white cards (5" x 8"). The width of the lines was approximately $\frac{1}{16}$ ", and the pictures were about $1\frac{1}{2}$ " high, although this varied according to the representation. The drawings were simplified by the omission of any unnecessary detail. This process, however, had different effects on the particular objects represented. The omission of extraneous detail from six of the drawings still rendered them identifiable to the adult eye, whereas the remaining six became rather ambiguous on /

GROUP I



GROUP II

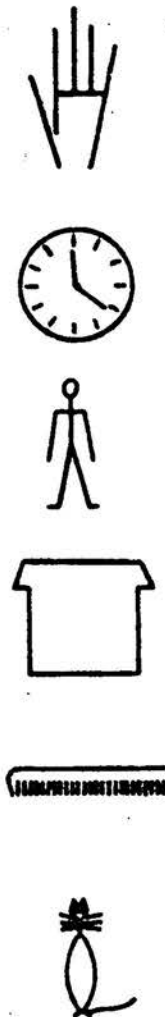


Fig. 27: Test 8 - ambiguous and non-ambiguous drawings of simplified objects.

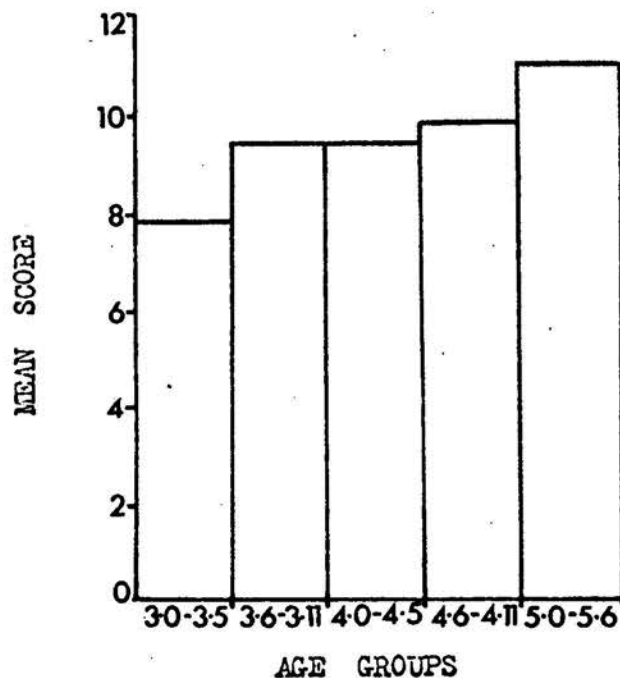


Fig. 28: Test 8 - frequency distribution of mean scores for each age group (appropriate recognition on twelve items).

on the exclusion of detail. It therefore became possible to place the twelve pictures in either of two categories a) ambiguous stimuli (by adult definition), and b) non-ambiguous (See Fig.27). Would this difference in the simplified drawings be similarly interpreted by pre-school children? In other words would there be greater generalisation of responses to the ambiguous stimuli (ambiguous by adult criteria)? It was important to discover if simplification of a picture necessarily led to ambiguity or if the retention of certain identifying characteristics would minimise this ambiguity.

Subjects: 110 nursery children took part in this study. Their ages ranged from 2.11. to 5.6. The distribution of ages was as follows:-

<u>AGE GROUP</u>	<u>FREQUENCY</u>
2.6. - 2.11.	1
3.0. - 3.5.	16
3.6. - 3.11.	24
4.0. - 4.5.	29
4.6. - 4.11.	29
5.0. - 5.6.	<u>11</u>

N = 110

Table 29 : Age distribution of subjects.

Presentation: Each card was presented in order at reading distance to the child. Before presentation, E said /

said: "I am going to show you some pictures and you will tell me what they are." When the card was placed in front of the child, E then said: "Look at this, and tell me what it is." The cards were presented fairly briskly, but S was given about ten seconds to reply. If he had not responded in this time, the card was quickly withdrawn and the next one in the series was presented. The response made was recorded.

Scoring: The responses were classified according to whether they were correct, appropriate, inappropriate, or non-responses.

Results: The distribution of appropriate mean scores for all twelve items in the series according to age is given in Fig.28. A 't' test for differences between the mean scores for age group 3.0. - 3.5. and 5.0. - 5.6. gave a value of 4.2 which for twenty-five degrees of freedom was significant beyond the .01 level of probability.

An analysis of mean scores in each of the four categories of response is given in the following table:-

<u>AGE GROUP</u>	<u>N</u>	<u>MEAN CORRECT RESPONSES</u>		<u>MEAN ERROR RESPONSES</u>	
		<u>Correct</u>	<u>Appropriate</u>	<u>NON-RES- :PONSE</u>	<u>IN- CORRECT</u>
3.0. - 3.5.	16	6.4	1.5	2.8	1.25
3.6. - 3.11.	24	7.5	2	1.1	1.3
4.0. - 4.5.	29	7.3	2	1.4	1.3
4.6. - 4.11.	29	7.9	2	1.3	0.8
5.0. - 5.6.	11	9	2	0.5	0.6

Table 30 : Mean scores in four response categories for five age groups.

Hereafter /

Hereafter, the total series is divided into the two groups of Ambiguous and Non-ambiguous figures.

The following table gives the percentage correct scores (correct + appropriate), percentage inappropriate scores, and percentage non-responses for each group of pictures:-

<u>GROUP I</u>				<u>GROUP II</u>			
(Ambiguous)				(Non-ambiguous)			
Item	% Appropriate	% Wrong	% Non-response	Item	% Appropriate	% Wrong	% Non-response
BALL	74	6	20	HAND	56	12	32
TABLE	64	14	22	CLOCK	100	0	0
WINDOW	90	1	9	MAN	95	3	2
CHAIR	64	26	10	HOUSE	91	5	4
TREE	69	8	23	COMB	94	2	4
BED	<u>53</u>	<u>27</u>	<u>20</u>	CAT	<u>95</u>	<u>2</u>	<u>3</u>
$\Sigma = 414 \Sigma = 82 \Sigma = 104$				$\Sigma = 531 \Sigma = 24 \Sigma = 45$			
p = .69 p = .14 p = .17				p = .89 p = .04 p = .08			

Table 31 : Percentages of Appropriate, Inappropriate, and Non-Responses for each group of pictures.

A ' \bar{z} ' test between proportions of appropriate scores in Group I and Group II gave a value of 3.7 which is significant beyond the .01 level. A similar ' \bar{z} ' test between proportions of inappropriate responses in the two groups gave a value of 2.3 which is significant beyond the .05 level (this test required the use of a correction factor because of $\bar{p}_e \times N_i$ being less than 10. The formula for this is given in Appendix III p.332, and for an explanation of this procedure, see Guilford 1956 p.222). A value of two was obtained for ' \bar{z} ' between non-responses in groups I and II, which proved to be significant beyond the .05 level.

The following table gives the number of categories of appropriate responses to each item in the two groups:-

<u>GROUP I</u>	N	<u>GROUP II</u>	N
BALL	16	HAND	4
TABLE	14	CLOCK	2
WINDOW	8	MAN	6
CHAIR	4	HOUSE	4
TREE	9	COMB	7
BED	<u>9</u>	CAT	<u>5</u>
	$\Sigma = 60$		$\Sigma = 28$
	Mean = 10		Mean = 4.7

Table 32 : Number of categories of Appropriate responses to each item in the two groups.

A 't' test between uncorrelated means in samples of equal size, was carried out between the means of appropriate categories for the two age groups. 't' was equal to 2.8, which for five degrees of freedom was significant beyond the .05 level. A ' χ^2 ' (for formula, see Appendix III p.332) was then carried out between the frequencies within each of these appropriate categories for Group I and Group II, and the tables of frequencies within the categories were as follows:-

<u>GROUP I</u> (f_e)	<u>GROUP II</u> (f_o)
169	87
307	508
76	39
27	11
19	7
15	5
12	2
9	1
7	0
6	0
3	0
2	0
2	0
2	0
2	0
1	0
1	0

Table 33 : Frequencies within each of the appropriate categories for Group I and Group II.

' χ^2 ' between these distributions was 254.6 which was significant beyond the .01 level of probability for fourteen degrees of freedom (see Table E, p.540, in Guilford /

Guilford 1956).

A Spearman Rank-difference correlation coefficient (r - for formula, see Appendix III p.332) between order of degree of generalisation (number of appropriate categories of response) and order of difficulty was found to be .38 which failed to reach significance at the .05 level (Table L, Guilford 1956 p.549).

Discussion: The frequency distribution of total scores with age shows an increase of appropriate naming of simplified pictures with age. This increase, however, is slight between the years 3.0. and 5.6., but nonetheless a significant difference was obtained between the scores for the youngest and the oldest age groups. The total mean score of appropriate responses (correct + appropriate) for age group 3.0. - 3.5. was 7.9. From this, it can be concluded that the naming of simplified representations of objects is already well-established by age three, but there is a continual steady improvement in this ability till about the age of five when the normal child should be capable of naming most representations of objects already familiar to him. The perceptual abilities necessary to relate a form representation to its object are probably fully developed by age five, and any difficulties in picture-naming at this stage will most likely be due to unfamiliarity with the object itself or to a representation in unfamiliar perspective.

Ambiguity /

Ambiguity in the items of the present test was originally operationally defined only with reference to children, in the following way: the experimenter arranged the pictures according to whether or not she considered them possibly ambiguous to the young child. This criterion for ambiguity took the form of lack of an identifying characteristic. It will be recalled that the process of simplification affected items in the series differently. It would have been desirable to give a definition of simplicity and ambiguity in terms of information content (from Information Theory), but the diversity of the forms did not facilitate such treatment. An analysis of the different categories of response for each group is shown in Table 31 (see p.149). An appropriate response was one which, though not necessarily conforming to the name given by the majority of children (and the experimenter) to the representation, nevertheless was a response which was appropriate to the stimulus in question. It will be remembered that a general tendency towards over-generalisation was already found to exist in the perception of pre-school children, particularly in the younger ones. This same tendency was found in responses to all simplified pictures. It was thought, however, that in the absence of a definite identifying feature, the young /

young child would be more likely to over-generalise the stimulus in keeping with his experience, associations, present needs, etc. A χ^2 test between proportions of appropriate responses in Group I and Group II was significant beyond the .01 level of probability. This indicated a real difference between the two groups of pictures. The non-ambiguous series of pictures elicited a significantly higher number of appropriate scores than did the ambiguous series. It must be noted that, provided the items in the two series were of equal perceptual difficulty, the ambiguous series should not have resulted in more incorrect responses, for any appropriate response (i.e. appropriate to the form of the picture) was given as much credit as a 'correct' response (i.e. majority response and the experimenter's original designation). It is possible, however, that the ambiguous series was not so much of a greater perceptual difficulty than of difficulty caused by the confusion which greater ambiguity probably incurred. This confusion might well lead to an inappropriate response, in some cases almost random naming, or to a non-response. The difference in error scores between the groups was almost equally accounted for by inappropriate responses and non-responses.

Thus, although all twelve pictures were simplified, the effect of this on certain objects was different from the /

the effect on others. For example, the form of the 'bed' is probably of the same perceptual difficulty as the form of the 'house' (both are simple geometrical-type forms), but the presence of the 'roof' on the latter is such as to make the form unmistakably that of a building whereas the form of the bed has no distinctive features. This would account for the fact that nine different appropriate categories of response were given to 'bed', as compared with four such categories given to 'house' (and two of these were part-responses to the whole e.g. 'roof' and 'chimney'). But the difference in inappropriate and non-responses to the two pictures is not thereby explained (47% errors on 'bed' and 9% errors on 'house'). It appears that lack of a distinctive identifying feature in the first picture was responsible for this difficulty in its interpretation. Although this difficulty was initially brought about by simplification, the same process on the other item 'house' caused relatively little difficulty because of the inclusion of the 'roof'. These difficulties were simply not ones of ambiguity where the child could still get credit for any appropriate response, but rather ones caused by confusion because of this ambiguity. The result of this appeared to be that the child either did not respond at all, or gave an inappropriate /

inappropriate response (names which did not appear even to have any associative value). It was thought that the six non-ambiguous pictures would produce a significantly greater number of non-responses than wrong responses as compared with the ambiguous series because of the above-mentioned inclusion of a definite identifying feature in the former. It was thought that the child, faced with a non-ambiguous picture and unable to name it, would be less likely to give another inappropriate name to the picture than to give a non-response. \bar{z} tests between proportions of wrong responses and non-responses in the two groups separately, failed to achieve significance at the .05 level ($\bar{z} = .62$ (Group I) and $\bar{z} = .94$ (Group II)). As can be seen, however, non-responses are greater than wrong responses in the non-ambiguous series compared with the difference in the ambiguous series, which tends to give some support to the hypothesis. Thus in the present test there was a slightly greater tendency to give no response rather than an inappropriate one to a non-ambiguous figure, as compared with the response to an ambiguous picture. This finding, however, is not sufficiently great for conclusions to be drawn beyond the present sample.

Table 32 p.150 gave the number of categories of appropriate responses to each item in the two groups. It /

It can be seen that the mean number of different categories of response for the ambiguous series was ten, and that for the non-ambiguous series was 4.7. A 't' test between the means of these samples gave a value of 2.8, which difference is significant at the .05 level. But when the frequencies of responses within each category are also taken into account (Table 33), the resulting χ^2 between the distributions of group I and group II responses was significant well beyond the .01 level. This result indicates a very clear difference between each group in the number of children who generalised responses and the number of different categories into which their responses fell. This indicates a further operational difference in response to the two groups of items which were previously differentiated by the experimenter.

It was previously supposed that a highly ambiguous figure which elicited many different responses from a group of young children, would also cause a certain difficulty due to confusion, and so be related to high error scoring (either an inappropriate response or a non-response). The rank-difference correlation between items ranked for degree of generalisation (number of different responses) and those ranked for error scores, was .38 which for the number of items involved, failed to reach significance at the .05 level. It would appear that /

that this low correlation was largely determined by one item 'hand' which was ranked second in order of generalisation and ranked eleventh in order of difficulty. Otherwise, there appeared to be fairly good correspondence between difficulty and generalisability. It is possible that that picture which is not instantly recognisable because of absence of a salient characteristic, is more likely to be seen in conformity with the child's experience, associations etc. But also, it is possible that this lack of an identifying feature would act so as to confuse the child and so generally lead to an inappropriate or non-response.

It must be remembered that many two-dimensional representational forms, are already schematised and simplified for children in their everyday experience e.g., the use of stick figures in drawings etc., and some objects in common use have been simplified to a great extent e.g., modern kitchen-clocks etc. It is not surprising, therefore, that these particular representations proved to have little ambiguity for children.

Conclusion: Simplification of a drawing (a process involving the removal of any unnecessary detail) need not interfere with children's recognition of the drawing provided a distinctive identifying feature is included.

Simplicity /

Simplicity of drawings should be an assistance to clear perception, but when a naming response is required from the child, drawings must not be simplified in such a way that their meaning is ambiguous. Non-ambiguity requires to be operationally defined, and it must be empirically established for any test item which requires a naming response from which inferences concerning the visual ability of the child are to be made.

4. Summary and Conclusions

Naming and matching were regarded as possible types of response for use in the subjective assessment of visual acuity in the pre-school child. At the same time, it was recognised that to use such responses for this purpose was to introduce a cognitive factor into visual acuity testing. For this reason, it was recognised that a test of sensory function required to be consonant with a child's cognitive and perceptual development. This section attempted to trace the development between three and five years of these types of response to a number of perceptual tasks.

A two-choice form matching test (pairs of geometrical shapes) showed a significant increase with age in performance, although the ability was well-advanced by the age of three. It was found that the consistent errors were made on items of 'similar' forms.

'Similarity' /

'Similarity' was definable in these instances as pairs of forms having the same number of sides.

When this aspect of 'similarity' was further investigated by means of a test using a four-choice matching situation (shapes of similar form), there was found to be a much greater increase with age in this ability. This task proved difficult to the average three year old who scored about 50% success. However, this performance also indicated that above-chance discrimination was taking place, and as a consequence, that other factors besides failure of discrimination were responsible for this error score. It was observed that higher distractibility and impulsive responses were characteristic of the younger age groups, in contrast with the deliberate scanning and fairly constant level of attention of the older children.

Pairs of pictorial representations similar in all respects but one, provided another matching task which showed a similar pattern of significant increased ability with age, although the ceiling for this test was arrived at by a much younger age group compared with previous non-pictorial tests. It was also found that a verbalisation of the difference between pairs required after the match of the child, was helpful in understanding his particular matching response. It was found thereby, that an incorrect match was sometimes due to causes /

causes other than faulty discrimination. That such verbalisation was also a help in the discrimination task itself was difficult to establish. It was also noted that instructions given to a young child were liable to certain types of misunderstanding or distortion which appeared possibly to be characteristic of this age group. For example, the category 'just like' included in all of these matching-task instructions was believed to be susceptible of different interpretations according to the verbal development of the child. However, although the introduction of pictorial material probably introduced other variables such as these into the test situation, the improvement at an earlier age in the resulting matching response (probably due to increased and sustained interest) was sufficient to justify this.

In another two-choice form matching task, after the match had been made, the child was required to verbalise the difference between the two key stimuli. The series was divided into two groups - pictorial forms, and symmetrical shapes - and when the difference was readily verbalised as in the picture series, this verbalisation became a better predictor of performance than age. In the shape series, however, when ability to verbalise the difference was less in evidence, age then /

then became the better predictor of matching ability. It was thought in the first case that the high degree of relationship between prediction of matching scores and verbalisation of the difference was due to the similar amount of cognitive ability demanded in both instances i.e. both were considered to be manifestations of intelligence. When verbalisation of the difference was not readily available as in the non-pictorial shapes, age then became the better predictor since in the majority of cases age would be in pace with mental development. There was no significant indication of a difference in one position eliciting better responses than in other areas, although differences in the top position appeared to be more readily perceived.

A letter-matching task using two sets of letters in vertical-horizontal and diagonal planes respectively, showed the same pattern of increased ability with age. A consistent type of error was noted to be present viz. attention to the upper part of a letter often to the exclusion of inspection of the lower part, resulting in confusion between letters of similar form e.g. E and F. There was also a marked tendency to confuse letters which were largely reversals of each other e.g. A and V. The ability to match correctly, however, was well-established by the age of three years.

A study of Part-Whole perception showed that the perception of the young child (about three years) appeared to be greatly determined not by the configural character of the stimulus material, but rather by a tendency to respond to the over-all characteristics of the stimulus rather than to its parts. This position was reversed by the age of about five, when a tendency to respond to details was apparent. These findings confirmed a direction which had been increasingly shown over the series of tests viz. the tendency of young children (about three years) to respond globally to the over-all characteristics of forms, and as a result, to over-generalise these forms in a matching situation. This finding of perceptual 'wholism' or syncretism in the three year old child has great pertinence to the visual acuity test-situation, since it appears likely in consequence of this tendency, that an assessment of the functional power of the visual system of the three year old child will be invalidated to a certain extent by those tests which demand the distinct perception of parts. This tendency to respond to the form as a whole is almost contrary to the Optometric principle (see Appendix I, p.279), where ideally the perception of a whole form should be determined by the discrete perception of its parts.

This /

This tendency which has been found in the perception of the three year old child, therefore, appears to call in question the validity of applying the Optometric principle as it stands at present, to any test-construction for this age group. The global nature of his visual perception is probably an attempt made by the child to simplify, for assimilation purposes, an otherwise too complex visual environment. The young child appears to impose broad categories on his sensory experience, but in no way does this indicate a deficiency of the sensory apparatus to define and discriminate small details.

Lastly, a test involving the naming response to pictorial representations of objects showed that simplification of a drawing can counteract this tendency towards perceptual over-generalisation. This process of the removal of any unnecessary detail, however, must not interfere with distinctive identifying features, which, if discovered empirically for a particular test item, can be used with success to assist the child in an identifying response to the picture.

3. A STUDY OF THE DEVELOPMENT OF FORM SENSE (VISUAL ACUITY)

1. Introduction

Visual acuity in the context of the present study has been defined as FORM SENSE (see INTRODUCTION p. 8). Traditionally, this 'sense' has been described as the capacity to discriminate small details or the ability to distinguish form. It is thus regarded, not only as a measure of the resolving power of the eye, but also as an aspect of form perception (previously defined as the way in which the child visually assimilates his external world - see p. 11). As it is conventionally tested, however, this aspect of visual perception is further restricted to the perception of black and white two-dimensional detail on a white background perpendicular to the direction of gaze.

Form sense, therefore, is a complex faculty, dependent not only on the optical, physiological, and perceptual power of the eye, but also on the ability to perceive form in that particular way defined by a given test. To study the development of Form Sense is, therefore, to study the development of a function i.e. form perception in operation. But in addition, it is also useful to trace the development of the basic structures in visual perception viz. the growth pattern of /

of the eye, refraction, and the development of primary and association areas in the visual cortex. In this connection, WEYMOUTH (1963) speaks of three phases involved in Form Sense:

- i) the OPTICAL PHASE of image production,
- ii) the PHYSIOLOGICAL PHASE involving stimulation followed by neural interaction and conduction in the retina and visual pathways, and
- iii) the PERCEPTUAL or PSYCHOLOGICAL PHASE, commonly assumed to be cortical, though some organisation may take place at a lower level.

It will be understood that the perceptual phase comprehends not only the reception of the stimulus in the visual cortex, but also the cognitive structures required in the particular test-response.

There now follows an account of studies concerned with the development of visual acuity in the pre-school years. At this stage, though, it will be useful to consider first a point made by PIRENNE (1962), which will be returned to later. By defining visual acuity as

"the reciprocal of the angle in minutes subtended by the smallest detail which can be seen under given conditions",

one is giving a purely operational definition. Pirenne continues:

" ... there /

"... there are in fact as many different 'visual acuities' as there are types of test object. A tendency to give visual acuity an ontological status has sometimes led to confusion."

This point should be kept in mind throughout the following discussion of results of previous visual acuity testing of children. The conflicting data depicting the developmental trend are an illustration of this point, and the point will again prove useful in solving the problem of the discrepancy between STRUCTURE and FUNCTION to be met with later in this section.

Assessments of discrimination in the very early years are limited by the response-capacities of the young child. The so-called subjective tests which depend on the child's ability to verbalise a given percept, or to respond in a meaningful way to a given stimulus, require a degree of maturation and learning not generally found before three years. Before this age, results are achieved chiefly on a more reflex level, and particularly by means of the eye's reflex movement to a succession of moving stimuli - the OPTOKINETIC RESPONSE (this is not strictly speaking a reflex action, depending as it does on a degree of attention; for this reason it has been termed a PSYCHO-OPTICAL reflex - KESTENBAUM 1957). Any response which requires voluntary activity, whether verbal or non-verbal, on the part of the /

the child, should not, strictly speaking be termed OBJECTIVE. A test should be termed objective only in so far as it accurately reflects perception without conscious intervention on the part of the subject.

The studies will be treated chronologically, then a composite picture of results will be abstracted. (Subjective testing results do not always indicate the nature of the test used, but where there is a lack of such indication, it can be assumed generally that the illiterate E test (see Appendix II, p.287), will have been used owing to its general acceptability in clinical practice.)

2. Review of Literature: The Development of Visual Acuity and the Growth of the Eye.

a) Objective studies*

The movement of the eyes toward a peripherally-appearing object is an OPTICALLY-ELICITED MOVEMENT (KESTENBAUM 1948). It is partly a function of the retina, but is also dependent on the presence of central vision. Thus at four-six weeks, the child may respond to a peripherally-presented flashlight or large object by turning his eyes towards the stimulus. A little later /

* NOTE: The few Objective studies which are mentioned at this point, are to be distinguished from the later comprehensive review: "Objective Methods of the Assessment of Visual Acuity". The studies in the present section are developmental studies showing the increase of visual acuity in the early years. Some repetition has necessarily taken place.

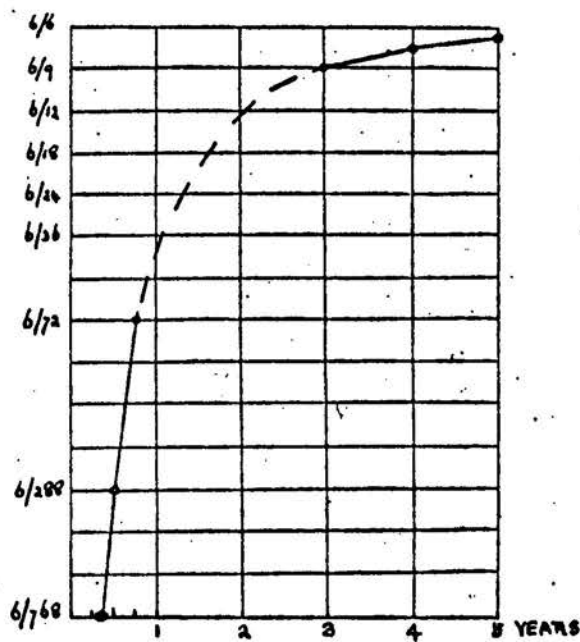


Fig. 29: Graph showing the development of acuity (Chavasse 1939).

later (five-six weeks) some attempt to follow a large moving object may be observed, but the movements are jerky in an attempt to keep the image of the moving object on the macula. It is not until four-six months that the movement glides, indicating the development of co-ordination of the central fixation and ocular motor pathways (HILL & STOCKS 1962). WORTH (CHAVASSE 1939) studied optically elicited movements. From three-four months of age, the normal infant's eyes followed a 1" black cube against a white background at a distance of two feet (corresponding to 6/768 vision - see Appendix I for an explanation of Snellen notation). By six months, the infant's eyes followed a $\frac{1}{3}$ " black cube at the same distance (6/288). By nine months, vision had improved to 6/72, and by one year, 6/36 was reached. By three years, vision had risen to 6/9, and 6/6 was not achieved until after five years (see Fig.29). (No reference is made to the nature of the test used with the older age groups, but it is probable that a subjective test was used for the later years.)

SCHWARTING (1954) also used the following reflex, using steel wires of different widths on a metronome moving at a rate of forty half-cycles per minute. Vision was tested in the dark at one metre with the wire moving across an illuminated field. The thinnest wire which elicited /

elicited a smooth synchronous following movement for at least one half-cycle indicated the visual acuity. The diameter of the test objects and their approximate Snellen equivalents were as follows: 1.5mm. (6/120)^{*}; 0.75mm. (6/60); 0.35mm. (6/30); 0.15mm. (6/15). The results of this method on a group of normal children were as follows:-

<u>AGE</u>		<u>ACUITY</u>
6 months	-	6/120
1 year	-	6/60
2 years	-	6/30
3 years	-	6/15

Table 34 : Visual acuity results in a group of infants (from SCHWARTING 1954)

(The very low value of vision at three years, is probably due to the limits of the stimulus viz. 0.15mm. viewed at a distance of one metre, rather than to the limits of vision at this age.)

OPTOKINETIC NYSTAGMUS is a similar type of reflex eye movement which is elicited by the eye following a succession of moving objects (for a fuller discussion, see the section on Objective Assessment p.218). It was claimed that the 'reflex' was dependent upon the presence /

^{*} NOTE: Conversion from the original notation.

presence of cerebral function, and as such, was not to be expected until central vision could take place (believed to be three-six months). GORMAN, COGAN, & GELLIS (1957), however, using this method, demonstrated that the response was present within the first few hours of life. These workers used a test pattern of alternating black and white lines, which occupied almost the entire visual field, and tested one hundred infants one and a half hours to five days old. The infants were placed in a crib and the pattern was rotated at a distance of 15cm. above their heads. Ninety-three of these infants responded to the stimulus which corresponded to a Snellen acuity of 6/201.* Do these results, therefore, indicate that form vision is present in infants as young as one and a half hours old, contrary to what was once believed?

Although optokinetic nystagmus generally appears only when objects in the visual field are attended to, and thus constitutes a cortical reflex with its centre in the visual cortex, SMITH (1937) using cats, and TER BRAAK (1936) in a variety of animals, demonstrated an optokinetic nystagmus in animals deprived of visual cortex. SPIEGEL et al.; (1944) also reported such a nystagmus in /

* NOTE: Conversion from the original notation.

in human amblyopic eyes, and he thus distinguished between the active and a passive type of nystagmus, the latter referring to this type of sub-cortical movement. He concluded from observations of the movement elicited in the newborn, in idiots, and in subjects in coma, that in man, also, a sub-cortical type of nystagmus may be produced. (For a fuller discussion of this problem, see p.230). This can be seen then as a direct criticism of the method of eliciting optokinetic nystagmus as a demonstration of central visual processes. The work of FANTZ (1958) however, lends support to the presence of central vision at a much earlier age than would be supposed from the anatomical and neurological evidence.

FANTZ (1958) provided another possible method of visual assessment in the young, when he noted that young infants tended to look at patterned surfaces in preference to homogeneous ones. His studies have indicated that pattern vision is not absent in the first months. (The work of Fantz has been referred to earlier p.22). However, he questioned the validity of the results of Gorman et al., for he claimed that structures which are important in the mediation of pattern vision - the central retina and the cerebral cortex - are not essential for the Nystagmic response to /

to pattern stimulation (FANTZ et al., 1962). Fantz believed that the 'voluntary' attention to the pattern of localised stationary objects represented a closer approach to functional pattern vision. This, therefore, formed the basis for his acuity test. His method is known as DIFFERENTIAL FIXATION. A striped pattern and a plain grey comparison object were presented above the infant (placed in a crib inside a test chamber) for twenty seconds. The results from thirty-seven infants (birth to six months) were obtained by observing the corneal reflections of the stimulus objects, and the main data analysis was based on the RELATIVE FIXATION TIME for patterned and unpatterned objects. His results gave a different picture of the development of visual acuity; pattern vision becomes progressively more acute, beginning with the neonate's ability to see stripes $\frac{1}{8}$ " at a distance of 10", and progressing to the seeing of $\frac{1}{64}$ " stripes at 10 or 15" distance, by six months. The results were as follows:-

<u>AGE</u>		<u>ACUITY</u>
0.5 months	-	6/120 [*]
1.5 months	-	6/120
2.5 months	-	6/120
3.5 months	-	6/60
4.5 months	-	6/60
5.5 months	-	6/30

Table 35 : Development of visual acuity from the neonate to six months (from FANTZ 1958-'62).

^{*} NOTE.. Conversion from the original notation

Fantz also attempted to relate these experimental results to others obtained by the method using optokinetic nystagmus (after Gorman et al. 1957). Close correspondence was found, a surprising finding in view of the supposedly different mechanisms underlying the two types of response. The main argument against the method of DIFFERENTIAL FIXATION, however, is that negative results do not necessarily mean inability to discriminate. On the other hand, positive results do tend to indicate the presence of central vision, and indeed, Fantz concluded that these findings implied that all parts of the visual system, from the optical apparatus to the visual cortical centres are functional soon after birth, however structurally immature they may be. Also, the marked improvement in discrimination which had been found during the first six months, was easily explained by the extensive maturation of the visual system known to take place during this period (in particular, the increased density of macular receptors, completed myelinization of nerve fibres, and improved skill in foveal fixation) (Fantz et al. 1962).

DAYTON, JANSEN, & JONES (1962) using the optokinetic nystagmus response technique with eight full-term infants, got results ranging from 0.125 to 0.080 (6/50 to 6/75). Two premature infants gave lower acuities. In /

In addition, their method used the oculogram as a recording technique. This refined method of measurement probably accounts for the high values of acuity found in these infants.

ORDY et al., (1964) in a study of the visual acuity in newborn primate infants, included forty-six human infants two to twenty-four weeks old. They argued that the evidence for the structural and functional immaturity of image-forming mechanisms at birth in man and lower primates, was based upon fragmentary experimental data. Also, they continued, since it is generally accepted that sensory maturation precedes motor development, it is highly likely that considerable visual development on the functional side has occurred before human and other primate infants can be trained to make appropriate differential responses from which sensory acuity thresholds can be inferred. For this reason, they chose the optokinetic response as an index of early vision. Their rationale for this choice is as follows:

"...Since appropriate oculomotor, optical and retinal mechanisms, as well as functional pathways in subcortical and cortical centres in the brain are essential for eliciting such co-ordinated visual pursuit responses in the higher primates, objective visual acuity thresholds have been established by this optokinetic nystagmus test in newborn primates..."

(Whether /

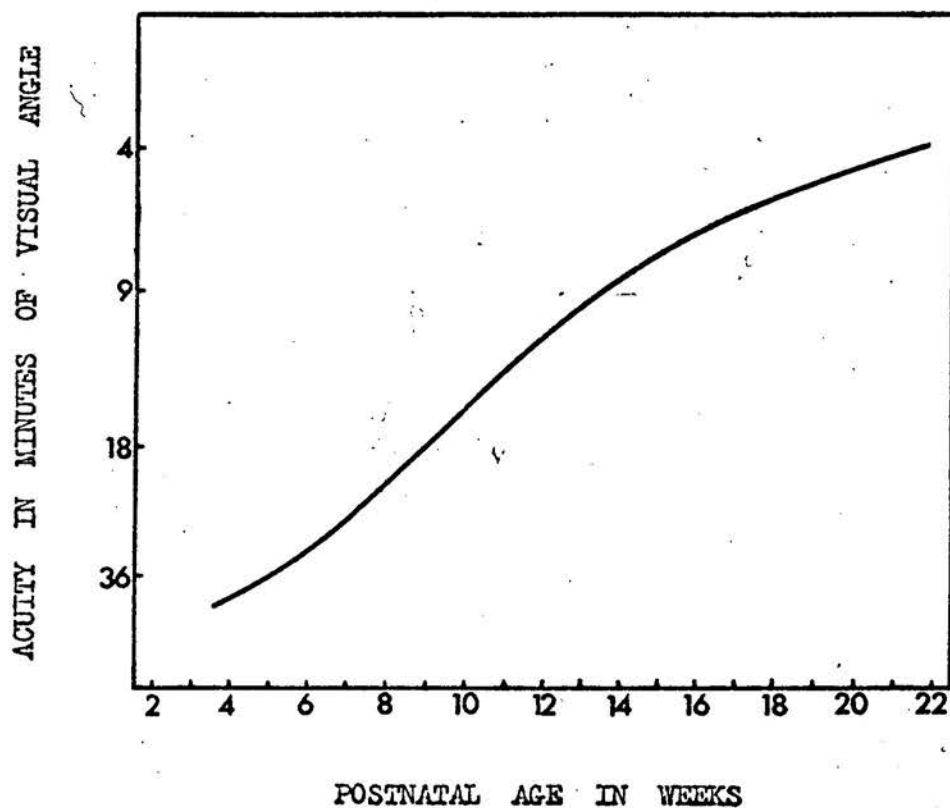


Fig. 30: Graph showing the development of visual acuity (estimated from the presence of optokinetic nystagmus) in infants 2 - 24 weeks old (from Ordy et al. 1964).

(Whether the presence of cortical mechanisms are essential to the presence of the optokinetic response in infants, is a debatable point - for a fuller discussion, the reader is referred to p.235). The patterns used, were four widths of vertical black and white stripes placed on the inner surface of four cylinders (each 16" high, and 22" diameter). The widths of the four sets of stripes were as follows:- $\frac{1}{8}$ " (corresponding to 36 mins. of visual angle); $\frac{1}{16}$ " (18 mins.); $\frac{1}{32}$ " (9 mins.); and $\frac{1}{64}$ " (4.5 mins.), all viewed at a distance of 12". A clear nystagmus was taken as the index of vision, and an estimate of visual acuity was obtained from the finest pattern of stripes which could elicit the following movement. The results are shown graphically in Fig.30. If these results are to be commensurable with the Snellen convention, then there is some question about the validity of using one stripe as the basis for the angular subtense. Not only should a black and white stripe be taken as the unit of measurement, but also the configuration of one of these units should subtend two minutes in order to be comparable with the Snellen notation (this is discussed in greater detail in a later section, p. 178). For it was stated in a recent review of visual acuity (WESTHEIMER 1965), that:-

"...If gratings (made up of equally wide black and white lines) are equivalent to/

to Snellen letters ..., a grating of one minute of arc width of each black or white bar, or half cycle per minute of arc, would correspond to 6/6* acuity."

(a comparable Snellen letter would subtend five minutes). This point must be emphasised for it is frequently overlooked in the construction of acuity grids. It is likely, therefore that the above results overestimate the vision of infants, for a much less demanding criterion (compared with adult acuity measurements on the Snellen scale) was used in the construction of the patterns. The pattern which was found to arrest the optokinetic nystagmus at six months (see Fig.30) and which was calculated as subtending 4.5 minutes, was in fact according to the Snellen convention, subtending an angle of nine minutes of arc, and should have subtended an angle of two minutes in order to have been comparable with Snellen 6/6 vision. For this reason the steepness of the curve of visual acuity is exaggerated. Vision at six months using this method (providing of course that the use of the optokinetic response is valid as an index of central vision at a cortical level), therefore has been recalculated to give a Snellen value of 6/27; and vision at two weeks was probably in the region of seventy-two minutes which by the Snellen notation corresponds to 6/216. This is very close to the results of /

* NOTE: Conversion from the original notation.

of Gorman et al., but is still subject to the criticism which has been levelled at all those studies using optokinetic nystagmus as the basis of their conclusions as to the presence of central vision. The liberty has been taken of recalculating the results of Ordý et al., for the composite graph (Fig.31). It is strange that Ordý should use this method in view of the criticism in the Fantz paper (1962) of which Ordý was co-author, that it was questionable whether structures which are important in the mediation of pattern vision - the central retina and the cerebral cortex - are essential for the nystagmic response to patterned stimulation.

Fantz's calculations are also incorrect since he bases his subtenses on the five minute convention and uses the width of one stripe in so doing. (NOTE that these calculations can only be designated as 'incorrect' if they are presumed to be comparable with Snellen acuity. Otherwise, they must stand as definitions of acuity in their own right - see the note on operational definitions of acuity p.166). If a graph of the development of a function is required, however, it is important to use the same convention for all measurements. Different methods, too, present a problem, which will be discussed later p.187. Fantz's results have also been recalculated for Fig.30.

b) /

b) Subjective studies

It has generally been accepted that most subjective tests cannot be successfully administered before the age of three years. (though DOLEŽALOVÁ 1964 has stated to the contrary) Those tests, however, which rely on behavioural responses - searching, grasping, etc., have the advantage of being free from the difficulties of communication, and therefore are more likely to elicit an earlier response from the child. Where sufficiently large numbers of children have been tested, there has been a marked concentration of cases in the higher acuities, which clearly indicates the high intrinsic capacity of the retino-cortical mechanism (WEYMOUTH 1964). Weymouth states that

"... agewise, the most difficult portion of the graph (of development) to assess has been that representing the acuity of infants and pre-school children. The objective acuities have been utilised, but both these and the earliest subjective acuities show glaring inconsistencies."

He continues

"... The sharp rise of acuity from birth to four or five years is an outstanding feature of the graph. In it are compressed both sensory and perceptual development of remarkable complexity. Even so, the curve probably underestimates this early rise."

SLATAPER (1950) defined visual acuity according to the Snellen convention, and combined the data from his own study with that of BROWN (1938). This gave a total of /

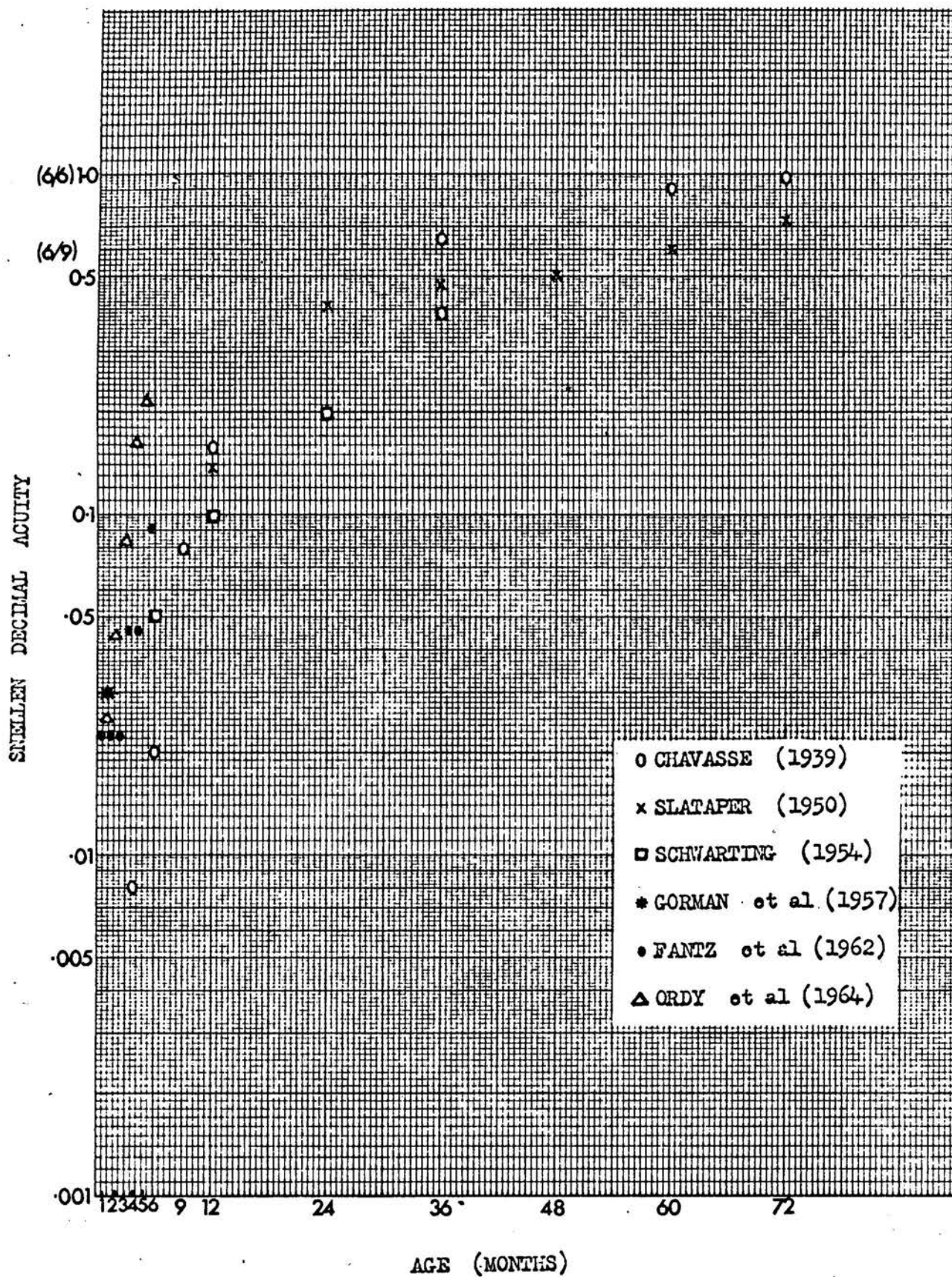


Fig. 31: Graph showing combined results of studies of the development of visual acuity from Birth to 6 years.

of 4,200 eyes below the age of eleven years. Acuity of the first year was estimated at $6/42^*$, but from two years upwards, the illiterate E test was used. Visual acuity was seen to develop on average from about $6/15$ at two years, to $6/6$ at twelve years. This is of particular interest since the results were obtained on one test (see later discussion p.188). MORGAN et al., (1952), tested 1,200 school children, using the Snellen animal, the illiterate E, and number and letter charts. These authors reported that about 32% of kindergarten children (about five years) had $6/9^*$ vision, 16.5% had $6/8$ app. vision, and 18.6% had $6/6$. Not until about seven years was $6/6$ average vision, and by age ten and eleven, $6/4$ vision was achieved by over 50% of the children tested.

PETERS et al., (1959) reported 94% of $6/6^*$ vision at eight years, and 96% at thirteen years.

These results are plotted on a logarithmic scale (Fig.31). There are discrepancies in the results, particularly in the various findings for the very early months, but a general trend is seen to emerge, viz. form vision, present though rudimentary almost at birth, greatly improves in the first few years of life. The graph climbs steeply from one to three years when it begins /

* NOTE: Conversion from the original notation.

begins to even off, although adult values of vision are not achieved on average until about nine years (twelve years - SLATAPER; six years - CHAVASSE; seven-eight years - MORGAN; and eight years - PETERS). Recent investigations, however, have suggested that 6/6 vision is average for three year olds (in Maryland, 5,279 children out of 7,249 had 6/6 vision - DAVENS 1966), and PECKHAM, as early as 1932 made a similar point. The generally accepted visual acuity performance of the three year old, however, still remains at 6/9 vision as the graph shows.

It will now be useful to compare this graph showing the development of function, with the pattern of development of structures as indicated by anatomical and neurophysiological studies of the growing eye and visual cortex.

c) Growth of the eye.

Of the four recognised patterns of growth, it is to the growth pattern of the brain and central nervous system (with its marked development in early childhood and subsequent slowing down) to which the eye belongs. This fact was recognised by WEISS as early as 1897. Growth of the eye is most spectacular during foetal development. By the end of the sixth month of foetal life, the eye has almost completed its development. Except for the macula/

macula and the dilator of the pupil, all parts of the eye are present and presumably capable of functioning. At birth, babies' eyes are about $\frac{2}{3}$ of adult size, averaging 17 $\frac{1}{4}$ mm. in their anteroposterior length, (from "The Eye in Childhood" 1967).

ORDY (1964) reports a finding of HORSTEN & WINKELMAN (1962), that histologic examinations of the development of the retina, macula, fovea, as well as rods and cones in newborn infants revealed shorter and thicker light receptors than those of adult subjects, but otherwise already well advanced structural development of the retina at birth.

WEYMOUTH (1964) states that the eye and C.N.S. show a markedly accelerated development in the foetal period, and the eye is far advanced at birth having attained an axial length of about 17mm.. By age three, the average length has increased to between 22.5 and 23.2mm., according to SORSBY, BENJAMIN, & SHERIDAN (1961). A measure of the precocity of the eye, continues Weymouth, is the fact that, although the volume of the body increases about twenty-one-fold from birth to the adult stage, the eye increases only a little over three-fold. This increase in the size of the eye affects chiefly refraction. The microscopic structure of the retina, in particular the fovea, which might be expected to /

to increase its fineness of grain, continues to develop at least for the first four months of life (MANN 1949).

HILL & STOCKS (1962), however, emphasise the fact that the development of vision is a complex process of intricate anatomic and neurophysiologic changes which is not complete until well after birth. The differentiation of the foveal cones continues throughout the first one-four months of postnatal life; medullation of the optic nerve fibres is completed in the first three weeks and other developmental changes in the iris, ciliary body, and lens, occur throughout the early years of life. Hill and Stocks state that to what extent the visual mechanisms of the cerebral cortex develop postnatally is not known, but recent electro-encephalographic evidence suggests that such development does occur at least up to the age of one year (STOFFT 1961).

TANNER (1961) draws attention to the agreement between cortex differentiation and motor function. In the development of vision, focusing the eyes on a distant object and blinking at a moving object appear at about three months, which is shortly after myelination of the optic nerve, and coincident with the maturation of the primary visual area in the occipital cortex. This functioning at the cortical level is, however, on a simple scale, not at a level involving any interpretive functions dependent on the association areas.

HIRSCH /

HIRSCH (1964) summed up by saying that recent work has shown how early in the life of the individual most growth of the eye is attained, and KEENEY (1951) noted that by the age of two years the cornea had attained its adult diameters.

SORSBY, BENJAMIN & SHERIDAN (1961) give a concise summary of the growth pattern of the eye. Growth of the eye falls into two distinct phases. Some time before the age of three years, rapid and extensive growth has brought the eye almost up to adult size and functional power. A slower, definitive phase occurs between the ages of three and thirteen years, during which time growth of the optical components is co-ordinated, axial elongation being met mainly by flattening of the lens.

HIRSCH (1964) concludes

"... That relatively complete growth is attained as early as the age of three is worthy of note. In this regard, the eye differs from other body organs. (However,) the mechanisms for co-ordinated growth of lens, cornea, and axial length during rapid growth of the first three years of life, and the mechanism for retaining co-ordination of lens and axis after the age of three, are still not completely understood."

The picture of the developing eye and visual system, appears therefore, to be one of negative acceleration, where there is a rapid spurt of growth during foetal life and from birth to the age of three, when growth is relatively /

relatively complete. Development after three years appears minimal in comparison, and seems to be of a more definitive nature. The development of function (visual acuity or Form Sense) shows the same pattern of negative acceleration, but in this case, maximal acuity is not reached (so it is generally claimed), until about nine years on average. It is true that the first phase of rapid growth of the eye and progressive maturation of the visual system is accurately reflected in the functioning power. And as the tests in the earlier years are more objective in nature with little reliance on cognitive intervention, the relationship between structure and function does appear to hold (although there are divergent results from different objective assessments). But as soon as results of subjective testing are introduced the following question becomes relevant: is functioning of the visual system as measured by subjective tests of acuity directly related to the stage of development of the resolving power of the eye, or is the relation impaired by the intervention of another variable viz. the ability to perform tests in general, to understand instructions, to respond in the required way, probably most accurately described as the development of cognition? (All tests of sensory function in the early years if they are of the subjective type, are subject to the limitations of the young child's level /

level of cognitive development. While strictly speaking, one should not attempt to regard these factors in isolation - as effective discrimination on a sensory plane is no doubt mediated not only by a properly functioning visual system but also by a necessary level of mental development - the object of visual acuity testing in the early years is for purposes of correction, and what is required is an assessment as near to the resolving power of the eye as possible.)

With these points in mind, the discrepancy between the development of structure and that of function becomes more intelligible. In fact, no discrepancy may exist between visual structures and potential visual function.

Let us consider the growth pattern of visual acuity. The graph (see Fig.31), is a composite picture, and it is necessary to remind ourselves of the tests from which these results were obtained. These were:- optically elicited movements (Chavasse; Schwarting), optokinetic nystagmus (Gorman et al.; Dayton et al.; Ordy et al.), visual interest and differential fixation (Fantz), Snellen animal (Morgan et al.), and the illiterate E (Morgan et al.; Peters; Slataper). What relationship do these differing methods bear to one another? One is at once reminded of Pirenne's dictum that there are as /

as many visual acuities as there are test objects. This composite graph, therefore, shows not the development of visual acuity, but the development of 'visual acuities'. This refers to all results with the exception of those of Slataper which were obtained from children of two years onwards and with the one test viz. the illiterate E. (His results for the first year were estimates). His results on average were as follows:-

<u>AGE</u>	<u>VISUAL ACUITY</u>
2	6/14.5*
3	6/12.5
4	6/11.9
5	6/9.8
6	6/8
7	6/7.7
8	6/7
9	6/6.96
10	6/6.7
11	6/6.1
12	6/6

Table 36 : The development of visual acuity from two-twelve years (from SLATAPER 1950).

These results, therefore, on Pirenne's criterion show the development of visual acuity as measured by the E test. A similar pattern is still observed but it will be noted that 6/6 vision is not fully reached until the age of twelve, and the average vision of the three year old child is about 6/12. Is this then a valid picture of the development of visual acuity? It appears to be /

* NOTE: Conversion from the original notation.

be, but it is limited by the definition of acuity implicit in its use viz. perception and representation of spatial orientation. These results therefore reflect the degree to which different age groups can cope with such a perceptual task. It is for these reasons that Pirenne continued:

"... A tendency to give visual acuity an ontological status has sometimes led to confusion."

There is no reason why a different task which is perhaps more appropriate to the level of mental development of the pre-school child should not reveal different results. A more realistic test for younger children might result in a picture of development of function which corresponded more closely to that of structure. The subsequent work in this section is an attempt to provide such a test of visual function.

3. The Study of Form Sense in the pre-school child.

Introduction: A study of the development of visual acuity should be a study of the measurement of the development of the capacity for discrimination of the visual system in quantitative terms. A study of the development of visual perception, however, is a different approach viz. a study of the way in which sensory development manifests itself at different stages of growth (see Note, p. 11). It has been said previously that such a study would take the form of a description of the way in /

in which the child visually assimilates his environment and would involve such questions as: "Are the forms of perception ready-made and 'given' in the infant child? Or are these basic structures achieved only after a slow learning process?" (The first question does not preclude the role of maturation. It is naturally accepted that an immature visual system is not capable of functioning at the power of the adult eye; but the first question goes on to ask..."Given this development with age in the functional ability of the human eye, is the perception of, say, form or depth, immediate, or does the child require learning and experience in addition to the maturation of structures in order to perceive these elements?")

Although these two aspects of perception viz. sensory potential and functional discrimination have been separated, it is a rather artificial division, for it is recognised that any test of sensory function must be consonant with the way in which the particular sensory activity will naturally manifest itself at that particular age. Consequently, the methods used for testing visual acuity in the young child and the results thereby obtained are subject to limitations, not only sensory (imposed by the stage of maturation of the visual system), but also 'perceptual' i.e., the limitations imposed by those determinants which regulate the way /

way in which the child perceives. To define visual acuity as discrimination illustrates this point. In the three year old child, it is possible that although the visual system has matured sufficiently to be capable of discriminating a small separation, perceptual activity has not yet reached the stage where the child will spontaneously respond to small details (see the previous studies p.49 and the work of VURPILLOT p. 34).

Studies concerned with the development of structure in the visual system (see Review of Literature p.182) have indicated that by the age of three years (the beginning of the pre-school period), maturation should have advanced sufficiently to allow functioning almost at adult level. These findings conflict with the generally accepted notion of the relatively inefficient visual functioning of the average three year old. A performance of 6/9 (Snellen) is widely accepted as the norm for this age group, though there have been outstanding objections to this (see PECKHAM 1932 and DAVENS 1966). In support of these latter findings are a host of reports of observations from teachers, parents, etc., of the striking discrimination demonstrated by pre-school children in their daily activities. It must be noted, however, that these observations /

observations have generally taken place when the child is performing ordinary tasks in the familiar surroundings of home or nursery school. It would seem that these circumstances favour good perception and discrimination in young children; but a clinical assessment requires the control of experimental conditions. Herein lies the difficulty - to decisively indicate good discrimination in young children, the necessary experimental conditions appear to limit the child's visual functioning and detract from the spontaneity of naturally-motivated 'looking'. This is the experience frequently reported by those engaged in assessing the vision of the young child.

In relation to this, it is helpful to consider a point made previously (p.167) about the need for operational definitions of acuity. Although discrimination has claim to an ontological status when considered as the potential of the whole system for resolution and perception, any assessment of this ability will reflect the nature of the method of assessment to as great an extent as the visual potential. This is particularly true in children where development of all functioning is so closely linked under the level of general ability. Only under conditions which favour the operation of good discrimination will such ability /

ability be revealed by the young child. Visual acuity of the pre-school child, therefore, will be a direct function of the suitability of the test for this age group. Are test conditions that widely exist favourable for the emergence of good discrimination? Since there is often a discrepancy between official test-reports of children's vision and accounts of visual ability in their everyday situation, it would appear that certain factors in the test situation are responsible for this apparent 'loss' in visual ability. What are these factors?

One of the most commonly mentioned defects in the acuity test situation is the distance which separates the child from the examiner. This factor has many undesirable effects on the child's performance, and the drawback which has had most recognition is by no means the most serious. This popular objection refers to lack of rapport with the young child, who will generally perform well in the close presence of adults and who is very susceptible to encouragement from close quarters. With increasing physical distance will come decreasing rapport, and the young child will not readily respond to an unfamiliar adult at a distance of six metres. Often, the child will spontaneously attempt to lessen this distance, a factor not allowed for in most test situations. To /

To overcome this difficulty, it has been widely recommended that testing should be carried out at three metres from the child, but even this is far from the ideal situation. But perhaps a more pertinent objection to distant stimuli, is the child's extremely inadequate localisation and fixation of an object in space. This is a pattern of behaviour frequently experienced by anyone who wishes to direct a child's gaze to a distant object. The child appears incapable on its own accord of detecting the object peripherally in order to fixate it. Such a situation generally will require that the child's head be turned to face the object so that the image falls on his direction of gaze. This frequently attested phenomenon recently has had some experimental substantiation (Lakowski & Aspinall, 1968). In this static perimetric examination of different age groups using the Goldmann perimeter, it was found in a group of young children that sensitivity to a spot of light was extremely poor at the periphery, whereas sensitivity at the fovea in the same group was comparable with adult values. (It was tentatively suggested that this relative insensitivity of peripheral systems in the early years (occurring in spite of adequate maturation of the receptor system) might be due to some sort of central suppression of peripheral function while foveal sensitivity reached adult /

adult standards.) This finding would account for the difficulty of fixation which appears to be experienced by younger children. An adult can usually detect a certain image on the periphery and turn his head in the required direction in order to fixate the object foveally. But a child will be seen turning in a complete circle in an effort to see what is being indicated to him. In pre-school visual acuity testing, therefore, there is always present the possibility that the child is not fixating the test object required of him. The examiner who is sitting close to the child can help to direct the child's gaze in the required direction.

As has been indicated previously, the choice of items and of the response which the child must make to many pre-school vision tests, is not in keeping with his stage of perceptual development nor with motivation. The abstract test situation requires to be made as stimulating and as natural as possible. Only then will a visual acuity test reflect the true ability of the child's visual system. The presentation of many test items has also been deficient. The difficulties of fixation normally encountered by the young child will be aggravated by test charts with over-crowded lines of symbols. For best acuity performance, therefore, the /

the child should be presented with single stimuli which motivate him to respond in a certain way and which are suited to his stage of perceptual development, by an examiner who is seated near him encouraging his co-operation and ensuring fixation.

Previous results and conclusions as to the lack of good discrimination in the pre-school child, appear therefore to be not so much a reflection of the incapacity of the visual system, as a direct result of the disadvantageous conditions of testing and the lack of realisation of the importance of the role of the child's stage of developing perception. The present study is an attempt to use principles of 'good' testing and discover the results on an operational definition of acuity in the pre-school child. DUKE-ELDER (1938) has urged that:

"... the value of any test in the investigation of visual acuity is increased in so far as composite patterns which necessitate psychological interpretations are eliminated from the test object."

In an investigation such as this, although it is recognised that a certain level of cognitive development is necessary, complete simplicity of test material will reduce cognitive interaction, and thus will be more likely to yield results of the child's visual ability than give an indication of his general level of test performance.

Description /

Description and Presentation: In order to allow the experimenter (E) to sit beside the child (S) and control his fixation and responses, the American Optical Co. Project-O-Chart (Table model No.1217) was used, with a standard slide holder. The variable focal length of the lens was adjusted to be used at three metres. The projector was fixed on a table behind which sat S and E. The distance between the screen and the child's eyes was three metres. Two slides had specially been prepared for the investigation of the 'minimum visible' and the 'minimum separable'. The projector had a built-in masking device which allowed for the presentation of single stimuli. The first slide consisted of a large clock face with its hand in the top position ('at twelve'), followed by sixteen smaller schematic clock faces each about 1" in diameter when projected. The projected outline of each clock was $\frac{1}{10}$ ". Four sizes of hand were represented placed randomly in each of the four cardinal positions (four successive positions for each size of hand - see Fig.32). The projected sizes and subtense at three metres were as follows:-

Clock / .



Fig. 32: 'Minimum visible' test.



Fig. 33: 'Minimum separable' test.

<u>CLOCK FACE</u>	<u>PROJECTED SIZE</u>	<u>SUBTENSE</u>	<u>SNELLEN EQUIVALENT</u>
1 - 4	4mm.	5'	6/30
5 - 8	2mm.	2'30"	6/15
9 - 12	0.8mm.	1'	6/6
13 - 16	0.4mm.	0'30"	6/4 approx.

Table 37 : Projected sizes and subtense of items in 'Minimum visible' Test.

Illumination of the screen measured by the S.E.I. Exposure Photometer, ^{was} /274 candelas per square metre (cd./sq.m.). The illumination of the background of the slide was 34 cd./sq.m., and that of the black figures was 0.6 cd./sq.m.. Each target thus had a contrast of 98% ($C = \frac{\Delta L}{L}$), which was quite adequate for visual acuity testing. The clock faces could be presented singly by means of the masking device.

The second slide was similarly designed. The first figure consisted of a large pair of black rectangles with a horizontal gap between them. This demonstration figure was followed by sixteen pairs of similar rectangular areas, six of them without a gap and the remaining twelve showing four different widths of space between the black areas (see Fig.33). The areas had a constant projected horizontal length of 1", and each of the four widths was the same as their intervening spaces (with the exception of the six solid rectangles /

rectangles). The dimensions of each projected target (width of the spaces or accompanying lines, and total width of the solid rectangles) with the subtense at three metres, were as follows:-

<u>TARGET</u>	<u>WIDTH OF LINES OR SPACE</u>	<u>SUBTENSE</u>	<u>SNELLEN EQUIVALENT</u>
1	4mm.	5'	6/30
2	2mm.	2'30"	6/15
3	Solid rectangle (Total width - 6mm.)		
4	2mm.	2'30"	6/15
5 & 6	0.8mm.	1'	6/6
7 & 8	Solid rectangles (Total width - 2.4mm.)		
9 & 10	0.8mm.	1'	6/6
11	0.4mm.	0'30"	6/4 approx.
12	Solid rectangle (Total width - 1.2mm.)		
13	0.4mm.	0'30"	6/4 approx.
14 & 15	Solid rectangles (Total width - 1.2mm.)		
16	0.4mm.	0'30"	6/4 approx.

Table 38 : Projected sizes and subtense of targets in 'Minimum separable' Test.

The positions of the solid rectangles in the target series were randomly determined. Illumination of the background was 34 cd./sq.m., and that of the targets was 0.6 cd./sq.m., giving a contrast of 98%. The masking device again allowed for single presentation of the figures.

On /

On the table in front of the child and within reach of his hand, was a small sweet-dispenser. E could control delivery by means of an off/on switch out of the child's sight. By pressing a button at the right time, the child could get a sweet from the mouth of the dispenser. Also on the table was a shaded desk lamp with a 100W bulb. This and the background screen illumination were the only sources of illumination throughout testing. The total lighting provided an illumination of 22 cd./sq.m., measured at the position of the face of the child facing the screen. This illumination was adequate to ensure that a state of light adaptation existed (Monjé 1958 states that a state of light adaptation exists when the illumination is 0.3 apostilbs (0.1 cd./sq.m.)). Sloan (1951) suggested twelve - eighteen millilamberts (approx. 38 - 55 cd./sq.m.) as a norm of illumination for use in visual examinations. The present background illumination approached this norm. This level together with the high contrast achieved between target and background, allowed the functioning of good visual acuity.

Presentation: Slide 1 ('Minimum visible'):- S was brought into the test room and seated comfortably beside E at the table. The back of the child's head was resting on the chair head-rest, thus ensuring constant distance /

distance from the eyes to the screen. The desk and projector lamps were then switched on and room lighting was extinguished. During the instruction time (lasting for no less than five minutes) S was adapting to the conditions of illumination. When she was sure that S was settled and attentive, E explained the task in this way:-

"Look at this (showing S a large white clock face with a moveable black hand). This is a special clock for it tells you when you will get a sweetie. You will get a sweet every time the hand of the clock looks like this (putting hand at '12'). When the hand of the clock looks like this, you are going to press this button (indicating button on the dispenser), and you will get a sweet. Try it and see (E's switch is in the 'on' position and she encourages S to press the button); S presses the button and receives a sweet.) You see, when the clock looks like this (indicating hand in the top position), you can press the button and get a sweet. But when the clock hand is here (moving hand into '3' position) you will not press the button because that is not the time for a sweet. Try pressing and see what happens (E's switch is in the 'off' position and S is not /

not rewarded). You will not get a sweet when the hand is here, so you will not press the button. (Positions '6' and '9' are similarly demonstrated with no reward.) So you see, it is only when the hand is here (pointing to '12') that you will press the button and get a sweet. Try it again and see. The game is for you to press the button only when the hand is here (pointing to '12'), because that is the only time you will get a sweet."

A few trials were then given with the large clock, until the child appeared to have grasped the idea of a critical position for reinforcement. A plastic occluder was then placed over the child's left eye (if there was any resistance, E told the story of a pirate and encouraged the child to wear his 'patch'. It was found that if this was placed on quickly and firmly and without fuss, the child rarely objected. Two of the sixty children refused to wear it and E tested these children with her hand over the appropriate eye).

E then said:-

"Now we'll play this game with the clock on the wall (projecting the demonstration target on to the screen). Look at the clock on the wall /

wall (E ensures that S is looking in the required direction by placing his head in position where necessary). Do you see the hand? Does it tell you that you will get a sweet? Will you press the button? (S presses the button and is rewarded). Now look carefully at this one (projecting the first test target). This clock has a tiny hand. Do you see it? Does it tell you that you will get a sweet?"

The procedure continued until all sixteen targets had been shown. The same procedure was then carried out with the right eye occluded, and only rarely did instructions require to be repeated for the second presentation. The subtense of the smallest hand correctly responded to (correct response to each of the four positions represented) was taken as the minimum visible to the child. This value was obtained for each eye separately.

Slide 2 ('Minimum separable'):- On another occasion, S was again seated beside E behind the table in the darkened room. E explained the new task thus:-

"This is a new game. Look at this (E shows S a cardboard model composed of two moveable rectangles). This is a sweet-shop, and the windows can open and close (E demonstrates the widening /

widening and closing of the gap between the rectangles). When the window is open, like this (E demonstrates), you can get a sweet. When you see that the window is open, you will press the button and get a sweet. Try it and see (switch is in 'on' position). You see, when the window is open, you can get a sweet. But when the window is closed (E demonstrates), you will not get a sweet. Press the button now and see what happens (switch in 'off' position). You will not get a sweet when the window is closed, so you do not press the button. But any time you see the window open, even a little bit, you should press the button because you will get a sweet. The game is for you to press the button and get a sweet only when the shop window is open."

A few demonstrations were then given with the moveable rectangles in the closed and open (various degrees) positions. Fewer trials were required since the children had previously performed task one. A plastic occluder was then placed over S's left eye as before, and E continued:-

"Now we'll play the game with the sweet-shop on/

on the wall. You must look carefully to see if the shop window is open. If it is open, you can press the button and get a sweet, but if it is closed, do not press the button. (E projects the demonstration target onto the screen.) Look at the shop.

Is the window open?"

E continued projecting the targets in this way. When sixteen figures had been shown, the same procedure took place with S's right eye occluded. The subtense of the smallest separation correctly responded to (in all presentations related to this subtense), was noted as the minimum separable for that child. Results for each eye were recorded separately. The children appeared highly motivated throughout both tasks.

Subjects: Sixty pre-school children from three Edinburgh Corporation Nursery Schools took part in the testing. There were twenty children in each of the three main age groups (3.0. - 3.11.; 4.0. - 4.11.; 5.0. - 5.6.). Testing was carried out soon after the children arrived at school in the morning, and after their mid-day rest. The children were taken in pairs from their nursery school to the Visual Laboratory of The Psychology Department, Edinburgh University, by the experimenter. The sample of sixty was randomly selected from a group of one hundred /

hundred and fifty children which had been refracted previous to testing (refraction was carried out by Dr. W.O.Petrie of the Edinburgh Corporation Health Department). All children in the sample were emmetropic.

Results: 1. Minimum Visible.

VISUAL ANGLES SUBTENDED BY SMALLEST LINE CORRECTLY

RESPONDED TO:

AGE GROUP 3.0.-3.11. AGE GROUP 4.0.-4.11. AGE GROUP 5.0.-5.6.

<u>AGE</u>	<u>R.E.</u>	<u>L.E.</u>	<u>AGE</u>	<u>R.E.</u>	<u>L.E.</u>	<u>AGE</u>	<u>R.E.</u>	<u>L.E.</u>
3.0. Non-testable	N		4.0.	1'	1'	5.0.	1'	1'
3.0.	N	N	4.0.	0'30"	0'30"	5.0.	0'30"	0'30"
3.1.	0'30"	0'30"	4.0.	0'30"	0'30"	5.0.	1'	1'
3.3.	N	N	4.1.	0'30"	0'30"	5.0.	0'30"	0'30"
3.3.	N	N	4.1.	1'	0'30"	5.1.	0'30"	0'30"
3.4.	0'30"	0'30"	4.2.	N	N	5.1.	0'30"	0'30"
3.6.	0'30"	1'	4.3.	1'	0'30"	5.1.	0'30"	1'
3.6.	N	N	4.3.	0'30"	1'	5.1.	0'30"	0'30"
3.6.	0'30"	0'30"	4.4.	0'30"	0'30"	5.1.	1'	0'30"
3.6.	1'	1'	4.4.	0'30"	0'30"	5.2.	0'30"	1'
3.7.	0'30"	0'30"	4.4.	0'30"	0'30"	5.2.	0'30"	0'30"
3.7.	N	N	4.4.	1'	1'	5.2.	1'	1'
3.7.	1'	1'	4.4.	0'30"	1'	5.2.	0'30"	0'30"
3.8.	0'30"	1'	4.5.	0'30"	0'30"	5.2.	1'	0'30"
3.9.	5'	N	4.5.	1'	1'	5.2.	0'30"	0'30"
3.9.	0'30"	0'30"	4.5.	0'30"	0'30"	5.3.	0'30"	0'30"
3.9.	0'30"	0'30"	4.6.	0'30"	0'30"	5.3.	0'30"	0'30"
3.9.	0'30"	0'30"	4.6.	0'30"	0'30"	5.4.	0'30"	0'30"
3.10.	0'30"	1'	4.7.	N	N	5.4.	0'30"	0'30"
3.10.	0'30"	0'30"	4.10.	1'	1'	5.5.	0'30"	0'30"

Table 39 : Visual angles subtended by the smallest stimuli correctly responded to (R and L eyes) for three age groups ('Minimum visible' Test).

ANALYSIS /

ANALYSIS OF RESPONSES: (Percentages)

	<u>AGE GROUP 3.0.-3.11.</u>		<u>AGE GROUP 4.0.-4.11.</u>		<u>AGE GROUP 5.0.-5.6.</u>	
<u>V</u>	<u>Right eye</u>	<u>Left eye</u>	<u>Right eye</u>	<u>Left eye</u>	<u>Right eye</u>	<u>Left eye</u>
6/4	55%	40%	60%	60%	75%	75%
6/6	10%	25%	30%	30%	25%	25%
6/15	-	-	-	-	-	-
6/30	5%	-	-	-	-	-
N (Non-testable)	30%	35%	10%	10%	-	-

Table 40 : Percentages of visual acuities
(R and L eyes) for three age
groups ('Minimum visible' Test).

2. Minimum Separable.

VISUAL ANGLES SUBTENDED BY SMALLEST SEPARATION CORRECTLY
RESPONDED TO:

AGE GROUP 3.0.-3.11. AGE GROUP 4.0.-4.11. AGE GROUP 5.0.-5.6.

<u>AGE</u>	<u>R.E.</u>	<u>L.E.</u>	<u>AGE</u>	<u>R.E.</u>	<u>L.E.</u>	<u>AGE</u>	<u>R.E.</u>	<u>L.E.</u>
3.0.	1'	1'	4.0.	1'	1'	5.0.	1'	1'
3.0.	N	N	4.0.	1'	1'	5.0.	1'	1'
3.1.	N	N	4.0.	1'	1'	5.0.	1'	1'
3.3.	1'	1'	4.1.	1'	1'	5.0.	1'	1'
3.3.	1'	1'	4.1.	1'	1'	5.1.	1'	0'30"
3.4.	1'	1'	4.2.	N	N	5.1.	1'	1'
3.6.	1'	1'	4.3.	1'	1'	5.1.	1'	1'
3.6.	N	N	4.3.	1'	1'	5.1.	0'30"	1'
3.6.	1'	1'	4.4.	0'30"	1'	5.1.	1'	1'
3.6.	2'30"	1'	4.4.	1'	1'	5.2.	1'	1'
3.7.	1'	1'	4.4.	1'	1'	5.2.	1'	1'
3.7.	1'	1'	4.4.	1'	1'	5.2.	1'	1'
3.7.	1'	1'	4.4.	1'	1'	5.2.	1'	0'30"
3.8.	0'30"	0'30"	4.5.	0'30"	0'30"	5.2.	1'	1'
3.9.	N	N	4.5.	1'	1'	5.2.	1'	1'
3.9.	1'	1'	4.5.	0'30"	0'30"	5.3.	0'30"	0'30"
3.9.	1'	1'	4.6.	1'	1'	5.3.	1'	1'
3.9.	1'	1'	4.6.	1'	1'	5.4.	1'	1'
3.10.	1'	1'	4.7.	1'	1'	5.4.	1'	1'
3.10.	0'30"	0'30"	4.10.	1'	1'	5.5.	1'	1'

Table 41 : Visual angles subtended by the smallest separation correctly responded to (R and L eyes) for three age groups ('Minimum separable' Test).

ANALYSIS OF RESPONSES: (percentages)

	<u>AGE GROUP 3.0.-3.11.</u>		<u>AGE GROUP 4.0.-4.11.</u>		<u>AGE GROUP 5.0.-5.6.</u>	
<u>V</u>	<u>Right eye</u>	<u>Left eye</u>	<u>Right eye</u>	<u>Left eye</u>	<u>Right eye</u>	<u>Left eye</u>
6/4	10%	10%	15%	10%	10%	15%
6/6	65%	70%	80%	85%	90%	85%
6/15	5%	-	-	-	-	-
6/30	-	-	-	-	-	-
N	20%	20%	5%	5%	-	-

Table 42 : Percentages of visual acuities (R and L eyes) for three age groups ('Minimum separable' Test).

1. MINIMUM VISIBLE TEST.

% in each Age Group with 6/6 Vision and better, and % with 6/4 Vision (Average 2 eyes).

<u>age</u>	<u>% 6/6 +</u>	<u>P</u>	<u>% 6/4</u>	<u>P</u>
3.0. - 3.11.	65	10.6	50	11.2
4.0. - 4.11.	90	6.7	60	10.9
5.0. - 5.6.	100	0	75	9.6

Table 43 : Percentages in each age group with 6/6+ Vision, and 6/4 Vision ('Minimum visible' Test).

2. MINIMUM SEPARABLE TEST

% in each Age Group with 6/6 Vision and better, and % with 6/4 Vision (Average 2 eyes).

<u>AGE</u>	<u>% 6/6 +</u>	<u>P</u>	<u>% 6/4</u>	<u>P</u>
3.0. - 3.11.	77.5	9.3	10	6.7
4.0. - 4.11.	95	4.9	12.5	7.3
5.0. - 5.6.	100	0	12.5	7.3

Table 44 : Percentages in each age group with 6/6+ Vision, and 6/4 Vision ('Minimum separable' Test).

Discussion:

1. Nature of the Test: These two tasks constituted very simple discrimination tests - the first one combined a minimum visible task with orientation, and the second was the simplest form of separation task. It is necessary, therefore, to consider these results in relation to the more complex acuity tasks such as letter discrimination, generally used in the adult test situation. In what way do these simple stimuli relate to more complex configurations, and what conclusions as to pre-school visual ability can be drawn from these results?

According to Snellen (1864) a normal eye can separate two lines so close together that their separation subtends 1'. His letter sizes (first published in 1862) were based upon the results of his investigations on the resolving power of the average eye. It is therefore implicit /

implicit in his thought that the perception of letters is effected (in spite of their total configuration) by means of a visual separation of parts. But later experience with his test types has shown wide differences in legibility among letters (see BENNETT 1965; RABIDEAU 1955; and SLOAN 1951). One of the reasons for these findings is that the legibility of any letter is a function of the Gestalt of which it is a part, and will vary with the total number and varieties of letters from which the testee can select in making his response (RABIDEAU 1955). Separation, therefore, while it must play a part in letter discrimination is certainly not the sole factor in operation. It is therefore difficult to generalise from performance on simple visible or separable tasks to the more complex discrimination of letters, although Snellen did not appear to consider this. For according to him, it would seem that since his letters were constructed on the basis of the 1' angle of separation, results from the simple tasks which were the basis of the present study should be generalisable to form perception.

Of greater relevance to the present study, is the factor analytic study of RABIDEAU (1955) of differences in visual acuity measurements obtained with eight different types of test target. He defined visual acuity /

acuity as the ability of the visual sense organ to resolve images of extremely small stimuli. He found that his group of eight targets consisted of sub-groups differing significantly in difficulty. The Snellen letter test was found to differ in difficulty from a dot-type positional test (Keystone Telebinocular), and Rabideau urged that great caution should be exercised in the substitution of visual acuity scores from one such test for scores on another. He stated that a visual acuity of $6/6^*$ on the Snellen letter chart and a dot-type test, means in each case, a different level of acuity. Thus the estimation of a subject's visual acuity is dependent upon the type of target used.

There are two main points to be made about these findings. The first concerns the necessity of a definition of acuity for each test-object used, and the second relates to the similarity between the dot test referred to by Rabideau and the 'minimum visible' test in the present study. As regards the first point, it will be remembered that a discussion took place earlier (see p. 166), regarding the fallacy of giving an ontological status to visual acuity. The statement of Pirenne has been corroborated by Rabideau's factor analytic study. Hence the importance of stating the nature of the test is once again stressed. It is therefore /

* NOTE: Conversion from the original notation.

therefore necessary to define visual acuity in the context of the present study. For example, in the 'minimum visible' test, visual acuity must be defined as the ability of the eye to resolve a small area of black against white, and in its particular orientation. The similarity between this definition and that provided by the Telebinocular Dot test is the second point to be considered. Rabideau's findings concerning the latter test was that it proved to be the most difficult test in the battery (as in the present study, the diameter of the dot was taken as the critical element.) At face value, this would appear a very simple test not subject to the difficulties imposed on form sense by complex patterns of letters. It must be remembered, however, that Rabideau's subjects were adults who would normally find letter discrimination an easy task. Yet difficulties with this type of minimum visible task were similarly observed by COWAN (1928) who concluded that a black dot on a white ground suffers from irradiation of the white, and so yields higher threshold measurements than do letters.

2. Conclusions from the Results: With the above definition of acuity in mind, and considering the conditions of testing, what conclusions are indicated by the results?

It /

It will be recalled that conditions were such as to favour good responses from the children. On the stimulus side, these conditions were, simplicity requiring no complex interpretation, single presentation, and reduction of the normal distance of testing to three metres. On the response side, the factors which favoured good responses were the close presence of E to the child permitting good rapport and ensuring proper fixation, and the reinforcing nature of the task which motivated an optimal performance from the children. Under these favourable conditions, visual acuity as defined above, appears to be well developed in the pre-school child. Values indicate that children of this age have better vision than generally they have been credited with. It is also interesting now to recall Davens' and Peckham's findings that young children have as good visual acuity as adults and that 6/6 vision from pre-school children is to be expected as the rule rather than the exception. (Also, see the results of testing in the present research using single E's at a distance of three metres p.253).

It is probable that Form Sense is not fully developed in the pre-school child in the sense that ways of perceiving characteristic of the child are such as to make his perception deficient compared with that of /

of the adult e.g., his tendency to over-generalise stimuli might render his perceptions inexact. But it would now appear that his visual system, at age three, is capable of making very fine discriminations when the stimulus is a simple one and the child is highly motivated to make such a visual resolution. From this study, therefore, visual acuity defined operationally as the ability to see small details of black against white in a certain orientation when motivated to do so, and the ability to resolve small white separations between black lines, appears well developed by the age of three years.

The smallest extension that was responded to by the majority of the pre-school children tested subtended thirty seconds of arc at the nodal point of the eye; but the majority of children responded to a separation subtending twice this visual angle (only a few resolved a separation of 30": but it is to be expected, judging from previous studies of these two dimensions, that threshold values for a separation task will be in excess of those for a minimum visible task). Thus the majority of three year old children (77.5% - average for the performance of two eyes) in this study could resolve a subtense regarded as the normal separation for the adult (cf. Snellen), although it is accepted /

accepted that this is a liberal norm, most adults being capable of resolving smaller details. However, a small group of emmetropic adults with 6/6 vision when shown the slide used in the present test, could on the whole only resolve the 1' separation. One may conclude, therefore, that provided a pre-school acuity test is in keeping with the understanding and interest of this age group, young children should achieve acuity values very close to those of the adult.

It will be noticed that seven children from the three year old group, and two from the four year olds were not testable on the 'minimum visible' test. It appeared that all of these children had not understood the critical nature of the position of the dot, and in consequence pressed the button when it was wrong to do so. In these circumstances, it was impossible to credit them with seeing the dot, although five of these nine children were able to correctly represent the position of the projected dot either by moving the hand of the large demonstration clock, or by pointing their fingers in the appropriate direction. It would seem therefore, that their non-testability was a function of insufficient understanding of the nature of the task rather than of inadequate visual resolution. A total of five children were not testable on the separation task.

It /

It can be seen, then, that the number of non-testable children decreased with age. It seems probable that this indicated greater understanding of the task and a general improvement with age in test performance, since there was no indication of increased visual capacity with age (threshold values of testable three year olds were equal to those of five year olds.) It is probable, therefore, that little or no acuity development was taking place between three-five years. However, results from previous perceptual tests (see p.49) showed that a great deal of perceptual changes were taking place between these years. Thus an acuity test which greatly involved form perception by using complex patterns for matching or for interpretation, might well indicate increased 'visual acuity' between three and five years. It has been shown from the present study that this will be due to age differences in perceptual ability rather than age differences in visual resolution.

4. Summary and Conclusions

The three year old should be perfectly capable of resolving a complex form, but how he uses this visual information and, indeed, just how much information he gets from the perceived form, will probably be greatly inferior to the perception of the five year old (see studies /

studies of Scanning p. 30). It seems then, that only in this sense can Form Sense be said to develop in the pre-school years. In the present sample, vision was as good at three years as it was in adulthood. Therefore there appears to be no real discrepancy between early development of visual structures and that of function. Form Sense will reveal itself according to the nature of the test. A task which is within the comprehension and interest of the three year old child, should reveal the good visual resolution of which he has shown himself to be capable.

4. AN OBJECTIVE STUDY OF VISUAL ACUITY

1. Introduction

The many difficulties which have been encountered in the subjective testing of visual acuity of pre-school children, might have been removed with the use of an objective method of assessment. In particular, the detection of amblyopia might have been facilitated by such a method. Certain authors who have been concerned with the vision of amblyopes, have attested to the errors such as those related to motivation and practice which have interfered with a subjective assessment (KUHNHART 1959, and REINECKE 1959, cited by REINECKE 1961). An objective method seemed to offer a solution to this problem of amblyopia detection. VOIPIO (1966), however, has shown that his objective method is not suitable as a basis for measurements of refraction, as his results showed a wide scatter between objective and subjective measures in astigmatic persons and in myopes when testing was carried out without correction. It is therefore, chiefly the possibilities which an objective assessment offers in the detection of amblyopia which is the concern of the present study.

Objective methods are only correctly named when they utilise a response which is outwith the conscious control /

control of the subject. VOIPIO (1961) and PEARSON (1966) have fully reviewed objective methods for assessing visual acuity. Pearson, however, perhaps erroneously, includes Worth's Ivory Ball test in this category. This test requires a searching or following response of the young child, and it is only in so far as this response can be called reflex, that such a method can truly be termed objective. Only reflex or conditioned responses will meet the requirements for truly objective results. Even the 'reflex' eye movement, optokinetic or 'train' nystagmus, does not quite reach this criterion of objectivity. It has been included among the 'psycho-optical' reflexes. MORRISON (1963) notes that the term 'psycho-optical' was introduced to describe movements which, though reflex-like in nature in the sense that they lie outwith voluntary control, still depend on attention to throw them into activity. Morrison states that the optical movements are mediated via the cerebral cortex. Thus, although it would be difficult to find a truly objective method, given the pre-requisite of attention, optokinetic nystagmus is very close to a reflex eye movement.

2. Review of Literature: Objective Methods of the Assessment of Visual Acuity.

From the literature, there appear to be five categories /

categories of 'objective' response potentially capable of a valid measurement of visual acuity (Voipio mentions four of these). It is not intended here to give an historical account of all methods of testing in each of these categories (for this purpose, the reader is referred to Voipio 1961 etc.), but a brief account will be given of the nature of each response together with characteristic ways of eliciting each response. The five categories of response are:-

- a) Oscillatory motion of the eye
- b) Optokinetic nystagmus
- c) Arrested optokinetic nystagmus
- d) Galvanic skin response (G.S.R.).
- e) 'Visual interest'.

a) Oscillatory motion of the eye

Goldman (1943) described a method using such a response. This oscillatory motion of the eye is a response of the eye in pursuit of a moving test-figure. Goldman's test figure was made up of an oscillating checkerboard band of squares, on a background of similar smaller squares. The test band could only be seen as discrete if the subject could resolve the elemental squares; otherwise, the band and background would fuse into one even gray surface. Thus the oscillatory motion of the eye could only be evoked if the eye could resolve /

resolve the details of the checkerboard test band.

SCHWARTING (1954) used a similar test with infants and young children. Thin steel wires of various thicknesses were made to swing from a metronome before a milk-glass window. Visual acuity was estimated from the diameter of the thinnest wire that was capable of evoking the oscillation of the eye (for a fuller discussion, see p.169).

b) Optokinetic nystagmus

BARANY (1921) was the first to successfully use this response from the human infant. The response itself, however, was first described by HELMHOLTZ (1866) in connection with the movements of the eye observed in a passenger gazing out of the window of a moving train ('train' nystagmus). It is defined as a "physiological reflex initiated by objects moving in a constant direction in the visual field in such a manner as to cause the appearance of a jerking type of nystagmus. The nystagmus consists of a slow following phase and a rapid recovery phase." (REINECKE 1961). It has also been termed a 'psycho-optical' reflex, however, because of the necessity of attention in order to elicit it. GUNTHER (1948) used a checkerboard ribbon moving across two rotating cylinders, which the subject saw through a small window (about 3° of his field of vision).

Visual /

Visual acuity was deduced from the size and distance of the ribbon pattern which elicited the response. This method has also been used with infants by GORMAN, et al., (1957). A strip with a grid-pattern was moved in a curve about 15 cm. above the infant's face. A positive optokinetic response was observed in ninety-three infants out of one hundred, one-five days old (see p. 171).

c) Arrested optokinetic nystagmus

OHM (1922) was the first to use this type of response. A horizontal nystagmus is evoked first by a coarse pattern, then it is arrested by a fine stimulus introduced into the field of vision. For his method, Ohm used a revolving drum with coarse stripes to elicit the movement, and small objects were placed between the drum and the eye in order to arrest the movement. The method has since been greatly refined and the most recent methods in this category are those of VOIPPIO (1961, and 1966), and WOLIN and DILLMAN (1964).

Voipio's method will be discussed in detail later.

d) Galvanic skin response

WAGNER (1950), used a method based on the galvanic skin response to an electric shock. By pairing the shock with the appearance of a certain figure, the experimenter conditioned the subject to respond with

a /

a fear response to the subsequent appearance of the figure. When the galvanometer registered a fear reaction to a wrong test type, it was concluded that the subject had not seen the target clearly.

e) 'Visual interest'.

This was a term coined by Fantz (1958) to describe the response of an infant to his method using differential fixation. It had been observed that young infants tended to fixate a patterned surface more than a homogeneous one, and this 'interest' response was used by Fantz as a method for the assessment of visual acuity (FANTZ and ORDY 1959). Infants from two-five months responded to stripes subtending a visual angle as small as eighteen minutes of arc, while younger infants did not respond consistently to the sizes of pattern used.

3. Relationship Between Objective and Subjective Methods of Assessment.

What is the relationship of these objective methods of assessment to subjective approaches? PEARSON (1966) gives the following table of correlation coefficients between objective and subjective measurements of visual acuity:-

METHOD /

<u>METHOD</u>	<u>r</u>	<u>STUDY</u>
1. Evoking Oscillatory Motion.	r = +0.91	LUSCHER 1955
GOLDMANN 1943	r = +0.91	de LAET & SZUCS 1959
	r = +0.90	FREUDENBERG <u>et al.</u> 1960
2. Evoking Optokinetic Nystagnus.		
GUNTHER 1948	r = +0.66	LUSCHER 1955
	r = +0.90	FREUDENBERG <u>et al.</u> 1960
REINECKE & COGAN 1958	r = +0.66	
REINECKE 1959	r = +0.91	
KORNBLATT & SAFERSTEIN 1963	r = +0.33	
3. Arresting Optokinetic Nystagnus.		
VOIPPIO 1961	r = +0.92	
WOLIN & DILLMAN 1964	r = +0.85	

Table 45 : Correlation coefficients between Objective and Subjective measurements of visual acuity (from PEARSON 1966).

WOLIN and DILLMAN in their study conclude that

"... there appears to be little question that objective measures of visual acuity which are highly equivalent to the commonly employed Snellen test can and have been developed and used."

Unfortunately, Pearson's review does not mention the subjective tests from which the relationships were obtained. The subjective tests used by Voipio and Wolin and Dillman, however, are known to have been the E test and the Snellen chart respectively. Their objective methods also, while similarly based on the arresting of optokinetic nystagnus, differed on the nature of the arresting stimulus. Voipio used a pattern /

pattern of equal areas of black and white horizontal stripes (a grid pattern corresponding to a Minimum Separable type of task), while Wolin and Dillman used a small spot of light which approximates to a Minimum Visible task. In spite of these differences, however, both objective and subjective tests in each study are highly correlated. But what is the relationship of Voipio's objective study to that of Wolin and Dillman? Are both methods comparable measures of visual acuity? In subjective testing, thresholds from minimum visible tasks are generally lower than those obtained from minimum separable tasks i.e., visual acuity is generally greater measured by a minimum visible type of target (but see RABIDEAU, 1955, for an instance to the contrary). Should this relationship continue to exist between objective measures of these two aspects of visual acuity? It appears that the greater difficulty imposed on the subject by a minimum separable task is related to subjectively experienced factors such as the difficulty of perceiving a gap between two black lines, as opposed to simply appreciating the presence or absence of visual stimulation as in the minimum visible tasks. (Minimum visible tasks, however, are believed to suffer from irradiation of the white background, so that physically they are more difficult targets to see). However in truly objective methods this experienced difference in difficulty /

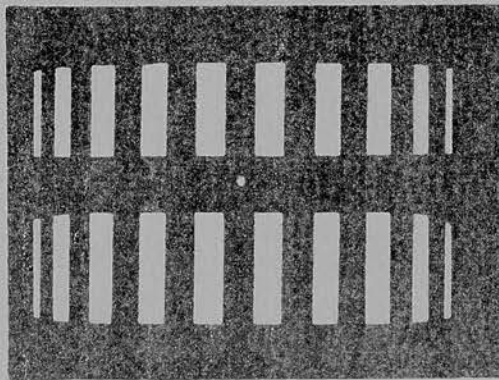
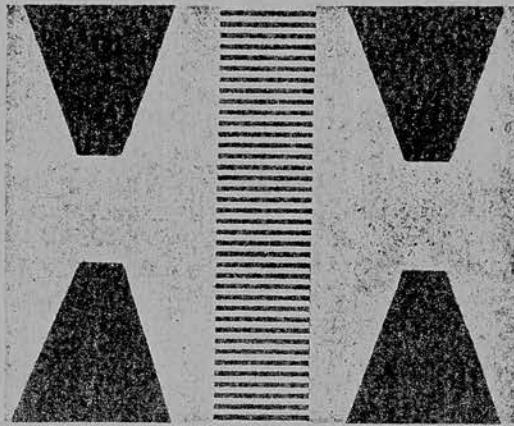


Fig. 34: Stimuli used by Voipio(1961) and Wolin & Dillman(1964) to arrest optokinetic nystagmus.

difficulty should be obviated. And provided the arresting stimuli are based on comparable Snellen equivalents (the diameter of the dot equal to 1', and the width of a black or white line equal to 1'), each type of stimuli should give similar visual acuity results. There is another factor to be considered in this connection, however. An inspection of the two types of arresting pattern used by these investigators (see Fig.34) shows that Voipio's grid covered the whole vertical central area of the screen whereas Wolin and Dillman used a small spot confined to the centre of the revolving drum and filling only a very small part of the visual field. Therefore, the arresting of the eye movement in the latter method would appear to depend largely on whether or not the eye was moving over the central area of the drum at the moment of introduction of the test spot. On the other hand, Voipio's method would ensure fixation on the arresting stimuli with any vertical height of the eye movement in the optokinetic reflex. This could account for the lower correlation obtained in the study of Wolin and Dillman.

With these points in mind, are all these supposed methods of visual acuity assessment measuring the same function? Previously, mention was made of the Snellen optometric principle and the relation of the empirically determined minimum visible and separable angles to the recognition /

recognition thresholds for letters, numbers, pictures, etc. Different legibilities of letters in the Snellen chart have shown that the incorporation of the empirical principle (1' and 5' convention) into the construction of any letters is not enough. Recognition has many more determinants than the one of discrimination. Thus, one cannot adequately compare letter recognition in the Snellen chart with for example, Vernier acuity, acuity with checkerboard patterns etc.

It is of interest here to refer to the factor analytic study of visual acuity targets carried out by RABIDEAU (1955). He used eight different test targets, four of which were lines of the Snellen letter chart. He found by a comparison of the factor loadings with previous studies carried out by the U.S. army, and by COOK (1948), that a single factor loading was present in all target performances. This he named 'RETINAL RESOLUTION'. His second factor axis represented a 'BRIGHTNESS DISCRIMINATION'. He concluded that:-

- a) Visual acuity thresholds depend on test object design and nature of the acuity test.
- b) The meaningfulness of Snellen letter thresholds is limited by the finding that letter difficulty and hence threshold, is a function of what letters are combined in the test.
- c) /

- c) Snellen letter targets yield finer thresholds than do non-letter targets.
- d) Caution should be exercised in comparing visual acuity measurements obtained with different types of target.
- e) Findings of factor analysis indicate that there are two (or more) kinds of visual acuity.
- f) There is some evidence to indicate that thresholds of visual acuity are related to area of black composing the critical elements of the various targets used in this study. The relationship of area of target design to threshold should be investigated with a view toward standardisation of test object dimensions.

Given these different factors in acuity tests, it still holds that correlations between two tasks (such as those involved in the subjective and objective relationship studies) will largely be determined by the factor of retinal resolution. Thereafter, other factors may enter and alter the positive relation. But given the limits of the resolving power of the eye, how far can objective 'resolution' be equated with subjective visual acuity? Here again one is faced with the erroneous /

erroneous consequences of considering visual acuity as an absolute value instead of as an operational definition. Both methods will yield assessments of visual acuity, but because different types of performance are required of the subject the definitions of visual acuity in each of these cases will be different ones and the results will most likely reflect this difference. There is no reason why one should expect an objective measure of acuity based on a response mostly outwith conscious control, to be exactly similar to a subjective assessment fraught with wide individual variations in motivation, cognition, reading ability, etc.

It is thus remarkable that such high correlations have been obtained, and the results do credit to the control of experimental conditions (see Voipio 1961). But one must not expect this as a necessary part of a study which seeks to compare these two types of methodology. In the testing of children in particular, it is highly likely that discrepancies due to difference in factors will be revealed. This is illustrated by a very recent study by SAVITZ and VALADIAN (1968) in which a test using optokinetic nystagnus was compared to a standard visual acuity test (the Titmus Screener test - a version of the Massachusetts Vision Test) given to 128 children aged three to six years. Both tests were reported to be comparable in ease of administration /

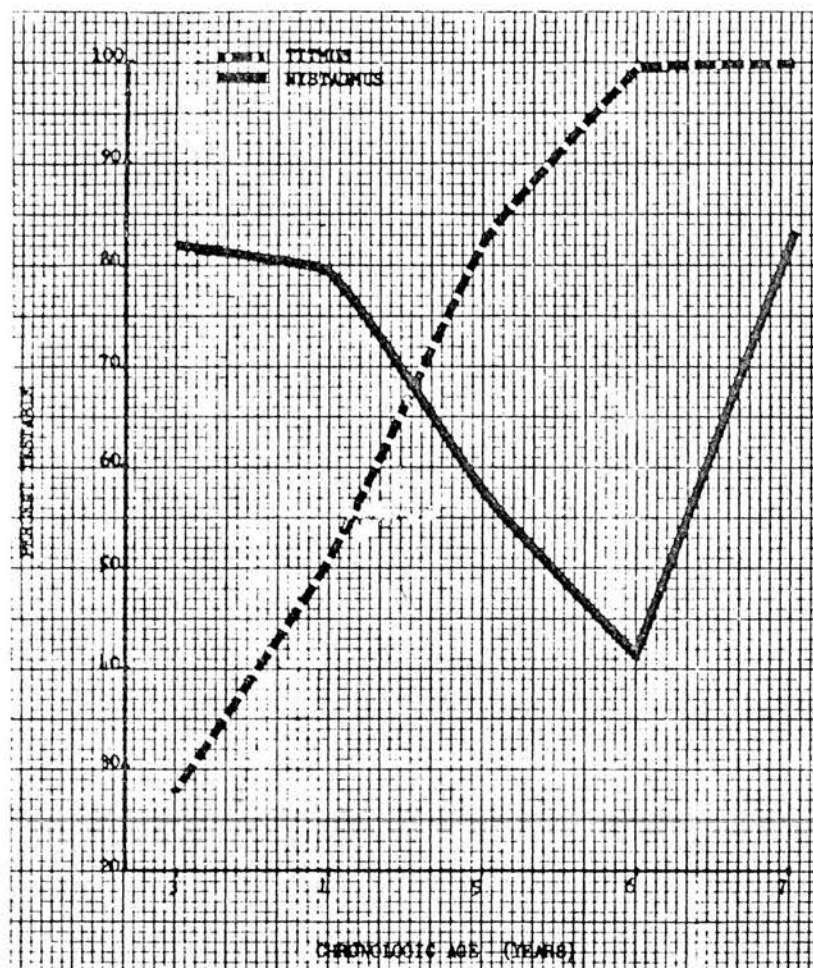


Fig. 35: Graph showing the dichotomy between objective and subjective measurements of visual acuity (from Savitz et al. 1968).

administration and speed of testing, yet a striking difference in age-specific testability was found. The younger children tended to be more testable with the objective test and less testable with the subjective test, while the reverse was true for the older children. The dichotomy was so evident that very few children co-operated equally well in the two tests for comparisons to be made (see Fig.35). The authors suggest in conclusion that it might be advantageous to use this complementary relationship in a screening programme to extend the range of testability.

It is now necessary to review the literature on the mechanisms of the reflex optokinetic nystagmus, since this seemed the most fruitful method of approach to the problem of objectively assessing the vision of the pre-school child. Can optokinetic nystagmus (ON) be regarded as a valid index of visual acuity?

4. The Mechanisms of Optokinetic Nystagmus (O.N.)

Optokinetic nystagmus (O.N.) has been termed a physiological reflex (REINECKE 1961), and is initiated by a succession of objects moving in the visual field (see p.221). The movement consists of a rhythmical back-and-forth motion of the eye, and is characterised by a slow pursuit movement following the direction of the objects, succeeded by a jerking return-movement. This /

This cycle is repeated as long as the stimulus is active and the subject looks at moving objects. The direction of O.N. is designated according to the direction of its quick component (by analogy with vestibular nystagmus to the rapid phase of which the quick movement of O.N. bears a resemblance - see SPIEGEL and SOMMER 1944 p.410).

The physiology of the optokinetic movement is such that the eyes tend to maintain fixation on an object moving relative to the observer. In the course of the slow pursuit movement, a certain point is reached (not necessarily determined by the fixated object reaching the limits of the field of fixation - ALPERN, in DAVSON 1963 Vol.3), when the eyes then return quickly and fixate upon another object which has just moved into the visual field. The process is then repeated.

KESTENBAUM (1957) has described the slow phase as "fixation of the eye on a moving object", and subject to three conditions:-

- a) a well developed and functioning macula,
- b) the presence of a moving object offering sharp contours, and
- c) attention to the object.

The speed of this movement is directly related to the speed of the moving stimulus, but the amplitude of O.N. depends on attention and the width of the visual field activated /

activated by the total array. Spiegel and Sommer (1944) also referred to the slow component as a "follow-up" or fixation movement. The mechanism of the quick phase, however, is still a controversial problem. According to Spiegel and Sommer (p.411) it was formerly assumed that the return jerk was a focusing movement ('Spahbewegung') elicited reflexly by the object that next appeared in the visual field. However, it was found that even with extensive damage to the visual field preventing the optically conditioned focusing movement, the O.N. was still able to be elicited (Kestenbaum 1930, Ohm 1922). Also the eye was found to return to its original position with a quick movement when the following movement was elicited by a single object (ter BRAAK 1936). Spiegel and Sommer (p.412), therefore, concluded that optically conditioned focusing of a succeeding object played only a minor role in the mechanism of the quick phase of O.N. Kestenbaum (1957) explained this movement as a return of the eye to the "intended direction of gaze". The movement is a "schematic movement" or 'Richtungsbewegung', and may be described as an "optically corrected schematic movement ... subject to normalcy of the corresponding muscles". Kestenbaum's conclusion was founded on observation of a case of disturbance of voluntary eye movements in one direction. Here he /

he observed an absence of the quick phase of O.N. in that direction. Spiegel and Sommer (1944) stated that the impulse to voluntary ocular movements could certainly influence O.N., as shown by the effect on the strength of O.N. of the direction of the gaze. But since voluntary gaze is actuated by the frontal lobe, and since both components of O.N. can be produced in spite of elimination of the frontal lobe, this cannot be the only factor. It is possible, therefore, according to Spiegel and Sommer that subcortical mechanisms play a part in the rapid component. It is probable, because of the similarity between the quick phase of O.N. and vestibular nystagmus, that the rhythm of the rapid movement originates in the vestibular nuclei.

However, O.N. as generally tested in clinical practice, appears only when objects that have caught the attention of the subject, move in the visual field. This type of nystagmus is "a cortical reflex with its centre in the visual cortex" (Spiegel and Sommer 1944). A second type of O.N., however, has been described by ter Braak (1936), which does not require attention. The first-mentioned cortical type he termed "Schaunystagmus" (glance nystagmus) while the second he named "Stiernystagmus" (stare nystagmus). SCALA and SPIEGEL (1938, 1940) have called the former "active" and the second "passive".

Evidence /

Evidence for the latter type has generally come from animals though there has been evidence that it might also exist in humans. ter Braak (1936) in a variety of animals, SMITH (1937) in the cat, Scala and Spiegel (1938) in rabbits, cats, and dogs, MORGAN and STELLAR (1950) in a variety of animals, and WALSH (1957) also in a variety of animals, found the presence of O.N., when all of these animals had been deprived of the cerebral hemispheres. PASIK et al. (1959), however, failed to elicit it in monkeys. Whereas this evidence points to a subcortical reflex, active nystagmus is believed to be cortical in origin since it is abolished by ablation of the cortical centres of the retina in the occipital cortex. The two types of eye movement, however, are further distinguished by the stimuli required to elicit them. The stimulus which elicits the sub-cortical O.N. is the movement of retinal images, and this type of O.N. is produced when all objects in the visual field are moved in the same direction (e.g. a very large drum covering the whole visual field). According to certain authors, a type of sub-cortical O.N. can be elicited in man. Ohm, Kestenbaum, and Spiegel have all reported observations of O.N. in cases of high degree amblyopia. de KLEYN (1948 - referred to by Kestenbaum 1957) has reported the case of a five year old child whose visual cortices were both excluded due to /

to a gas-intoxication. The cortical O.N. (elicited by a series of moving objects) was absent, whereas the 'sub-cortical' O.N. (elicited by rotation of the entire surroundings) was present. This observation led de Kleyn to accept the existence of a sub-cortical O.N. in man also. In addition, Spiegel and Sommer (1944) conclude from observations of the reflex in the newborn, in idiots, and in subjects in coma, that a sub-cortical type of O.N. may be produced in man. They also quote many experiments which suggest that the vestibular nuclei play an important part in the mechanism of passive O.N. ter Braak (1936) suggested a distraction of attention from the moving objects (in contrast to the conditions for active nystagmus) in order to induce passive nystagmus e.g., a stationary point of fixation is brought into the centre of the field of vision, and the subject looks at it while the objects are moved across. The same effect is achieved by requiring the subject to concentrate on a mathematical problem while looking at the eliciting stimuli.

Since these two types of O.N. can be differentiated on the basis of the stimulus used to induce the movement, it is essential that in the examination of central visual acuity the stimulus used is such as to induce the active type of O.N. This fact, however, seems /

seems to have been ignored. For example, in the experiment reported by Gorman, Cogan, and Gellis (1957) where a striped pattern of fine vertical lines was moved in an arc above the faces of very young infants, O.N. induced in the majority of these infants was taken as an indication that central vision was present in the newborn. The authors proceeded to draw conclusions as to the visual acuity of these infants. It will be noted, however, that wide stimulation such as that used in this experiment was found to induce the subcortical type of O.N. In fact, Spiegel and Sommer (1944) used such evidence from newborns (where it is supposed that central vision is not yet taking place due to immaturity of the visual structures) to indicate the presence of passive O.N. in humans!

One must therefore be cautious in using O.N. as an index of visual acuity in view of the possibility of a passive nystagnus appearing under certain conditions. The method to be recorded now, that first introduced by Ohm (1922) and lately greatly developed in Finland by Voipio (1961, 1966) viz. the arresting of O.N. by a pattern which requires to be resolved before the arresting process can take place, is a surety that central vision is in fact being assessed by an objective method.

5. The Work of Voipio (1950 - 1966)

Voipio has been developing his work from 1950, having /

having based it on Ohn's principle viz. the assumption that the seeing of the object which is used to arrest O.N., is dependent upon the resolving power of the eye. Voipio's study of 1961 was the culmination of this work, and his method has been improved upon in the paper of 1966. In the first study, he was concerned with three things:-

- a) can the arresting of O.N. be used for examining visual acuity?
- b) is his apparatus suitable (at least in principle) for the purpose? and
- c) what is the relationship between subjective and objective measurements?

The principle of his method was as follows:-

A wide O.N. is evoked with a series of objects in uniform motion (a double rack pattern or sawtooth). A large grating-figure made up of horizontal black and white lines is suddenly introduced into the field of vision. The essential feature of the method is that the appearance of the grating figure is not accompanied by any change in the total illumination of the stimulated field - only a redistribution of light is permitted. If this condition is satisfied, whether or not the subject sees this figure will depend solely on whether or not the eye can distinguish the elements of the grating and not on a detection of a brightness increment. The size of /

of the elements of the smallest grating-figure capable of arresting O.N. is then taken as an objective estimate of the subject's visual acuity.

The apparatus (1961) consisted of a projector (with remote control) mounted on a stand. A black and white film with a symmetrical double rack pattern passed the projector gate. Simultaneously, another film was inserted in the gate. This comprised a series of ribbon-like figures formed by gratings of black and white lines of equal thickness with a smooth gray surface on either side of the bands. This gray background was chosen empirically as one into which the bands would merge when they could not be resolved (or were out of focus). The length of the projected lines was 20cm., and the widths of pairs of projected black and white lines varied as follows:-

<u>Height of 1 Pair of Lines</u>	<u>Relative Size of Line Unit.</u>
6.5mm.	1.0
9.4mm.	1.4
14mm.	2.2
19mm.	2.9
23mm.	3.6
36mm.	5.6
48mm.	7.4
60mm.	9.3

Table 46 : Heights of one pair of lines, and relative heights of line units.

The average contrast between the black and white elements was 90% (the contrast value differed a little from slide to slide owing to the photographic process; Voipio, however, quotes LINKSZ (1952) as considering a minor variation in contrast to be of little consequence in the study of visual acuity). The size of the stimulating field was 80 x 120cm., and the total illumination was 40 lux (12.7 cd./sq.m.). The speed of the moving film was given as 15-18° per second (this means that in 10 seconds 20-25 teeth passed the centre of the test area on the screen). The subject sat at a distance of 4.5 metres from the test area in a darkened room which eliminated any possible 'arresting' factors in the environment (contours etc.). A total of 366 eyes were tested, and the arresting of O.N. was visually recorded. On the same occasion, subjects were also given the E test under identical conditions, an E-chart slide being used in the projector.

Results showed that O.N. did not develop in twenty-six eyes, and was faint in eighty-four eyes. In a total of 239 eyes a wide clear nystagnus was reported, and there were seventeen cases of a varying response. Voipio reported that the arresting effect on O.N. of the grating was clear. The movement of the eyes stopped shortly after the appearance of the grating and no latency /

latency time could be observed in typical cases. As the visibility of a grating will depend considerably upon a possible astigmatic error of refraction, the tests were carried out with fully corrected refractive errors. The results were such that the reaction of the eyes to the grating figure showed a "clear and simple relationship to the subjective visual acuity" ($r = +.92$).

VOIPIO and HYVARINEN (1966) repeated the study with an improved Voipio apparatus and electronystagography. This modification of the method, they have called Arrestovisography. It is relevant to mention a few of the alterations to the original method. The distance of testing was increased to five metres and the total illumination was increased to 400 lux (137 cd./sq.m.). The velocity of the moving pattern was also greater - 30° per sec. i.e. 33 teeth pass the middle of the screen in 10 secs. Recordings were made by placing two rectangular silver electrodes 5 x 8mm. on the skin of the temples, which were connected to one of the channels of a two-channel ERG recorder. The neutral electrode was placed on the forehead. The width of the grating-figure elements and the duration of sharp focus of these were also registered by an electrical marker device built into the projector and connected to the other channel of the recorder using D C amplification. The marker /

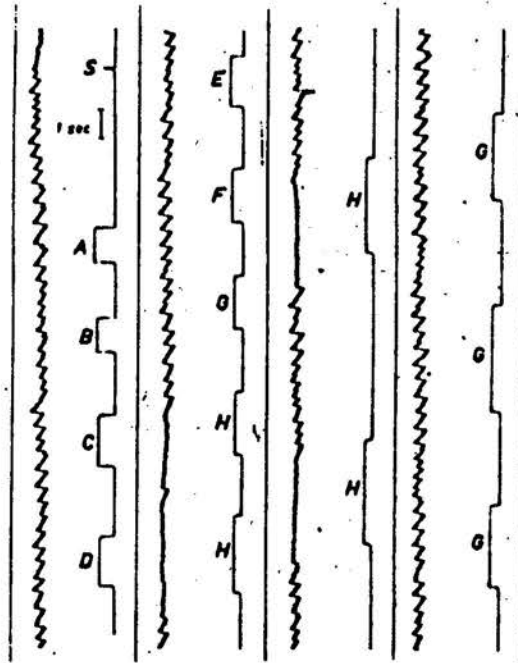


Fig. 36: Recording of the arresting of optokinetic nystagmus (from Voipio & Hyvarinen 1966).

marker also produced a spike impulse when the optokinetic stimulus was started or stopped (see Fig.36 from Voipio 1966). The width of the smallest pair of lines was again 6.5mm., and thereafter the width increased logarithmically by 26%. Fifty-eight eyes were tested with this improved technique. To ensure that active O.N. was being elicited the stimulating area was not wide. Again, a clear positive correlation was obtained between subjective Snellen acuity and the arresting grating-figure.

It is necessary here to question one aspect of Voipio's work. If the subjective and objective methods were to be comparable measurements of visual acuity i.e. with the optometric principle in common, then a pair of black and white lines in the smallest grating figure (supposed to be equivalent to 5/5 (6/6)* vision) should have subtended 2' rather than 5'. WESTHEIMER (1965) stated:-

"If gratings are equivalent to Snellen letters or Landolt C's, a grating of 1' of arc width of each black or white line, would correspond to 20/20 (6/6)* visual acuity."

Since it is believed that the separation of the elements of the subjective test item is critical for recognition (i.e. areas subtending 1' of arc, and not the total 5' subtense /

* NOTE: Conversion from original notation.

subtense of the whole figure), a separation of the same dimensions should be required in the objective technique in order that both methods be comparable. Thus Voipio's smallest grid on this reckoning would have been equivalent to a subjective target two-and-a-half times the size of the 5/5 (6/6)* E. In spite of this error of calculation, however, Voipio's method seemed to be the most promising approach to the objective assessment of visual acuity in the pre-school child.

6. The Study: The Arresting of Optokinetic Nystagmus Without Change in Illumination.

Introduction:

From the previous discussion, it was concluded that Voipio's method, based on Ohm's principle, was probably the best approach to the problem of the objective measurement of visual acuity in the pre-school child. Some experience with Voipio's method in Finland in 1965 (testing ten children five-seven years), led to the conclusion that variations in attention to the moving film ^{are} ~~was~~ responsible for the large differences in quality of O.N. observed. These variations were particularly noticeable in the performance of the younger children. On the whole, however, the method appeared to have definite /

* NOTE: Conversion from original notation.

definite possibilities for use with pre-school children. The present study was an attempt to apply this method (in principle) to a sample of younger children and to assess the validity of such a method as compared with a subjective assessment made on the same occasion. The following questions were thus asked:

- a) is this method suitable for the objective assessment of acuity in young children? and
- b) what relationship do the results of such a method bear to a subjective assessment in the pre-school child (bearing in mind the limits imposed by the difference between the tasks - see p. 229)?

Apparatus:

The apparatus consisted of three matching 35mm.

Rank /

Rank Aldis Tutor 500 Projectors* with lenses of focal length 15cm. (f/3.5 Aldis Anastigmat), and a white mat screen three square feet. The projectors were fitted with 300W tungsten projector lamps (matched for equal brightness with an S.E.I. photometer). The first projector was used to carry a film loop, and for this purpose was fitted with an induction motor geared to give /

* NOTE: In each of his studies, Voipio used one projector which carried both the film loop and the stationary grid-patterns. In the present study, it was decided for convenience to use two matched projectors to carry each film separately. The photographing of the grid-patterns, however, brought what proved to be a prohibitive difficulty at the time viz. achieving a grey background into which the grids would merge completely when seen out of focus. This is the basis of the method, in that the grid must not be visible as a total pattern of brightness, but must depend for its being seen on the discrimination of the black and white elements. Because of restricted time, it was therefore decided to provide this exact shade of grey background by means of a third projector the lens of which was fitted with an iris diaphragm. The central black band on one of the two slides on this projector, perfectly covered the area produced by each of the projected grid-patterns, so that the reduced light forming the exact shade of grey required, fell only on either side of the grid-patterns. As a result, the method was rather clumsy but sufficiently effective for the present purpose. Any routine clinical usage of such a method, however, would require the use of a refined technique similar to the improved Voipio apparatus (1966).

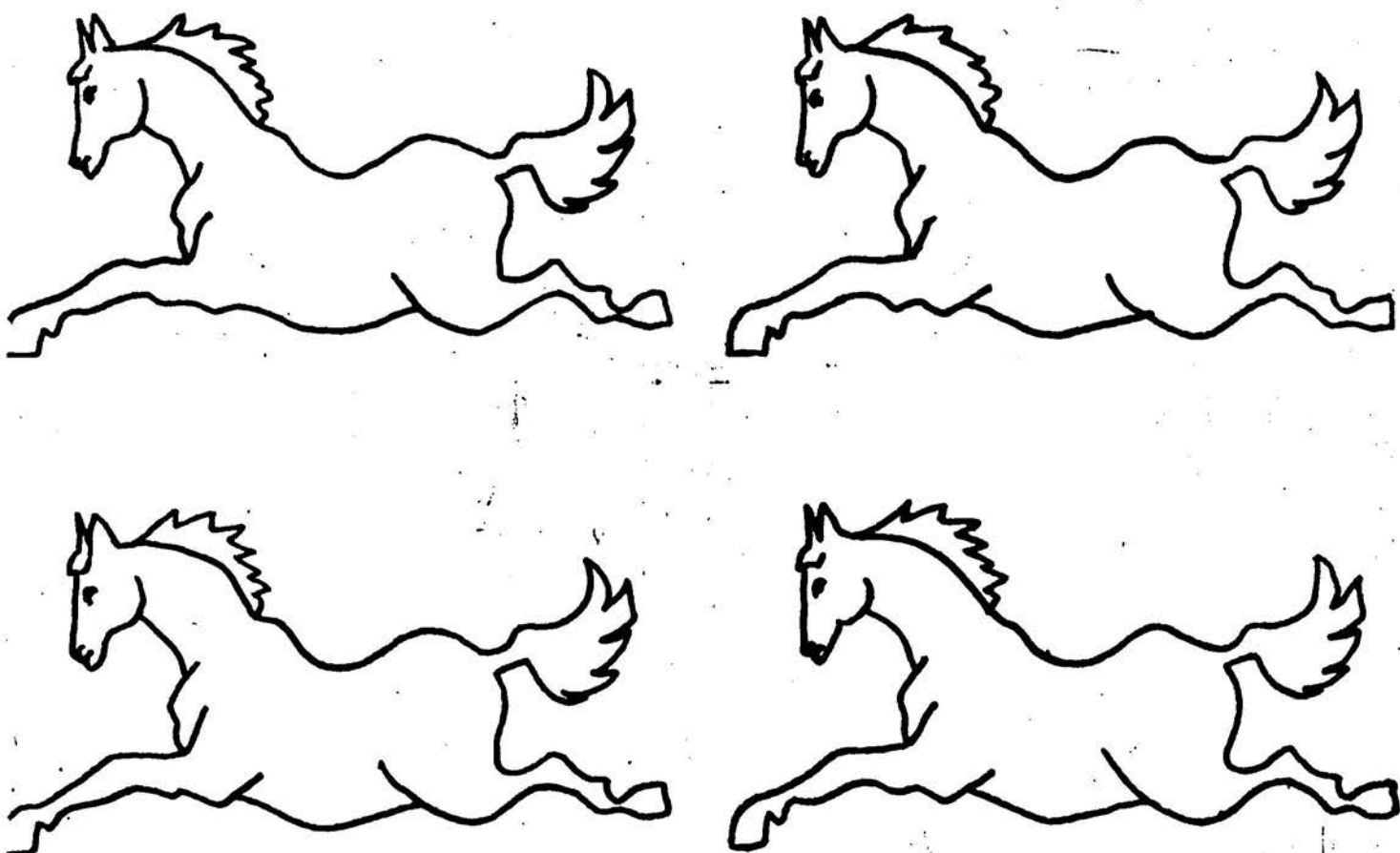


Fig. 37: Double pattern of horses used in the construction of the film loop for inducing optokinetic nystagmus in young children.

give 23r.p.m. on the film drive wheel. The film loop consisted of a double pattern of outline leaping horses on a 35 mm. film (see Fig.37). When projected, each horse measured 29cm. in length, and 15cm. in height at its widest points, and the projected outline was approximately 3mm. Between each horse was a space of 9cm., so that almost two horses filled the projected picture size (65 x 42cm.). The velocity of the film was 13⁰ per second (fourteen horses passed the centre of the screen in ten seconds). The second projector was fitted with the standard slide carrier assembly, and an iris diaphragm was fixed in front of the lens (see Note, p.244). The slide carrier contained a blank 35mm. slide and another 35mm. slide with a black bar running vertically down the centre. The dimensions of the black bar corresponded exactly with the dimensions of the five grid patterns on the film strip carried by the third projector. These grid patterns consisted of different sizes of equal-width black and white horizontal bars, each pattern being positioned in the centre of a black background. Between each pattern and its background (comprising a 35mm. space), there was a black area corresponding to a 35mm. film area (the array is shown in Fig.38). The projected lengths of each grid pattern was 18cm., and the widths of the elements of the /

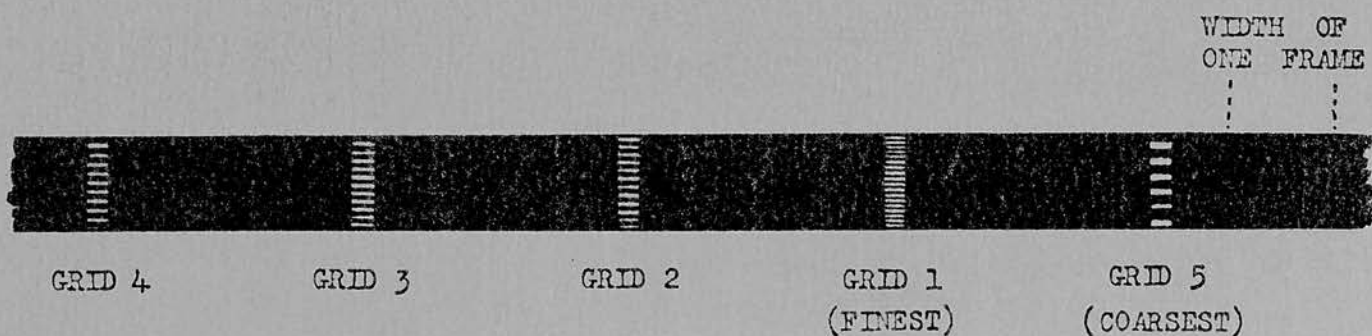


Fig. 38: Array of grid patterns (arresting stimuli) on film strip, with interspaces.

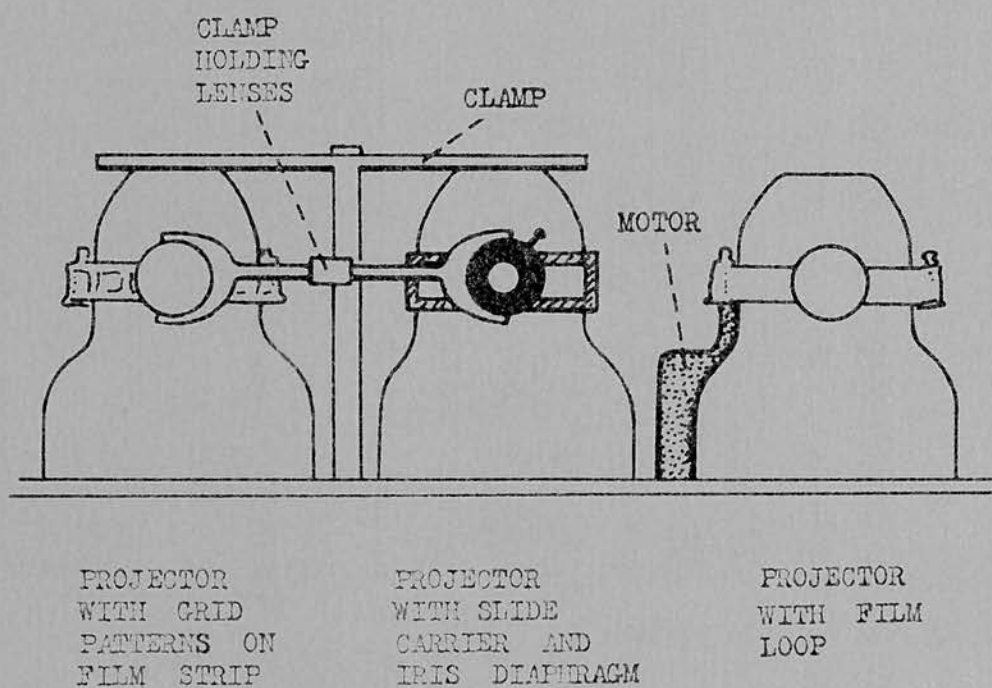


Fig. 39: Diagrammatic representation of the apparatus used for the arresting of optokinetic nystagmus without change in illumination.

the five different patterns when projected were as follows:-

1. 1mm. (width of a black and white line).
2. 2mm. (" ").
3. 3mm. (" ").
4. 4mm. (" ").
5. 14mm. (" ").

Table 47 : Projected widths of black and white elements of five patterns.

Great care was taken in the photographic process to ensure that the contrast between the black and white lines did not vary markedly (a little variation did take place), and that the lines did not lose their equal spacing. The luminance of the black and white elements was measured by an S.E.I. Photometer, and contrast was calculated from the following equation:

$$C = \frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}}, \quad \begin{array}{l} \text{where } L_{\max} \text{ is the} \\ \text{luminance of the white} \\ \text{elements, and } L_{\min} \\ \text{the luminance of the} \\ \text{black elements.} \end{array}$$

This is known as MICHELSON CONTRAST. Where it is not possible to state clearly which is the background and which is the test area as in the case of alternating light and dark bars of equal width, the above is the more acceptable definition of contrast - BOYNTON (1966).
Using /

Using this formula, contrast was found to be 88%. The total illumination of the screen from all three projectors was 304.3cd./sq.m.. When the pictures from the projectors were perfectly aligned, the lenses of the projectors carrying the slides and the grid-pattern film strip were clamped together, and the projectors fastened securely to the table used in the testing by means of a T-bar (see Fig.39). This ensured stability of alignment throughout testing (this was essential in view of the modifications which required to be made to the original technique - see Note p.24). A low chair for the subject was placed in front of the table, so that the projector beam was projected over the subject's head. The screen was placed at a distance of three metres (about ten feet) from the subject's eyes.

Procedure:

Testing was carried out in a darkened room in order to eliminate any extraneous arresting factors from the test situation. Each child, having been refracted on a previous occasion, was brought into the examination room by the experimenter who was familiar to the children through constant visits to their nursery schools. The child sat on the low chair and was allowed to adapt to the screen illumination (three projectors were switched on) for about five minutes. A little head-rest on the chair /

chair ensured that the child's head was held at the necessary distance. E sat on a low chair slightly in front and to the right of the child. She quickly placed a plastic occluder over the child's left eye and the film loop was set in motion. The other projectors had the blank slide in place (No.2), and only a frame of the black background of the grid-pattern film strip showing (No.3). The child's attention was directed to the 'jumping horses'. After a short interval during which E noted the quality of the nystagmic response, the film strip was deftly turned so that the coarsest grid pattern appeared in the centre of the field, and at the same time the slide with the black bar corresponding exactly with the area of the grid was introduced (a great deal of practice was necessary to ensure that both film and slide were introduced simultaneously). The coarsest pattern was first introduced to test the arrestibility of the O.N. Thereafter, the finest pattern was presented, followed where necessary by progressively coarser ones until the O.N. was successfully arrested. The patterns were arranged in this order to facilitate speed of testing. After the arresting grid-pattern had been recorded, the right eye was then occluded and a similar procedure took place using the left eye. Between each presentation of a grid-pattern, the totally black area was in place in the gate of the strip projector (3) and the /

the blank slide was shown from the slide carrier on the second projector (2).

When an assessment of both eyes had been made with this method, the child was then shown the finest grid with its gray background (provided by reduced illumination) and asked for a subjective report of what he saw. The grid-pattern was increased in width where necessary until the child reported that "lines" or "stripes" were seen in the middle of the picture. S was then given a short rest during which time an American Optical Co. Project-o-chart was switched on to allow the child to adapt to the change in screen-illumination. After this period, the child once again sat on the test chair, and the single E test was carried out monocularly right, then left, as before. The children had been previously trained in the use of the E figure - imitating with their large E the direction of the pointing bars - at their nursery schools. Using this method of presentation, the single E's presented a contrast value of about 90% (somewhat greater than the contrast of the grid pattern, but not significantly so according to Linksz - see Voipio 1961 p.46). Thus the conditions for the two methods of testing were roughly the same. The children were allowed to adapt to the illumination of both situations, and contrast was increased only by a small /

small amount in the subjective test situation. The total testing time for each child lasted for about thirteen minutes. Since nine minutes of this time was given to adaptation during which the child was playing, duration of testing was not too long, although the children did show signs of restlessness towards the end of the test period. Speed of testing was important throughout, in order to preserve the child's interest and to prevent fatigue. It was also necessary that this sense of speed should not be imparted to the child who was allowed plenty of time for his responses to the subjective test. It was found that children responded more positively to a lively and brisk presentation of items. A certain amount of practice was necessary to ensure smooth testing. From the test situation, two pairs of observations were obtained for each child - the relative heights of the minimum E figure correctly responded to and the minimum arresting line unit (line and space) for each eye. In addition, a subjective response of the finest grid-pattern resolved, was obtained from each child.

Subjects:

Forty pre-school children took part in the study (a total of eighty eyes). Their age range was as follows /

AGE /

<u>AGE</u>	<u>FREQUENCY</u>
3.0. - 3.11.	1
4.0. - 4.11.	18
5.0. - 5.5.	<u>21</u>
	<u>40</u>

Table 48 : Age distribution of subjects.

This group was drawn from a sample of children who had previously been refracted. Thirty-one were emmetropes, eight were low hypermetropes, and one was a myope (corrected). The children were enrolled in three Edinburgh Corporation Nursery Schools, and were taken from school to the Visual Laboratory of the University Psychology Department first thing in the morning, and shortly after the children's mid-day rest.

Results:

The quality of the nystagmic responses to the moving horses was noted for each eye, and analysis of the results in percentages is given in the following table:-

<u>TYPE OF NYSTAGMUS</u>	<u>N</u>	<u>%</u>
+ + + clear, wide nystagmus	28	35
+ + small but regular	35	43.75
+ small and irregular	14	17.5
- no observable nystagmus	<u>3</u>	<u>3.75</u>
	<u>80</u>	<u>eyes.</u>

Table 49 : Analysis of quality of Optokinetic Nystagmus (O.N.).

The /

The following table gives the qualities of nystagmus grouped according to subjective visual acuity results:-

<u>Subjective</u> <u>visual acuity</u>	+++	++	+	-	<u>Total</u> ...
6/4 (1.5)	5	2	-	-	7
6/6 (1.0)	16	26	9	2	53
6/8 (0.75)	2	1	-	-	3
6/16 (0.375)	3	2	1	1	7
6/20 (0.3)	2	2	1	-	5
6/24 (0.25)	-	-	1	-	1
6/36 (0.166)	-	2	2	-	4

Table 50 : Qualities of Optokinetic Nystagmus grouped according to subjective visual acuity results.

The following table gives the visual subtenses at a distance of three metres of the smallest targets resolved in both subjective and objective tests. In all a total of seventy-seven pairs of results are given on account of failure to elicit optokinetic nystagmus in three eyes :-

Subjective /

[illegible]

Heights of test figures, their relative heights, and logarithms of these relative heights are given in the following table.

<u>SUBJECTIVE TEST (E figure)</u>			<u>OBJECTIVE TEST (Line unit of arresting grid.)</u>		
Height of E	Relative Height	log.	Height of lines	Relative Height	log.
3mm.	0.75	1.8751	-	-	-
4mm. (6/6)	1.0	0	1mm. (6/6)	1.0	0
6mm.	1.5	.1761	2mm.	2.0	.3010
7mm.	1.75	.2430	3mm.	3.0	.4771
9mm.	2.25	.3522	4mm.	4.0	.6021
13mm.	3.25	.5119	14mm.	14.0	1.1461

Table 52 : Heights, relative heights, and logarithms of test figures in the subjective and objective tests.

The height of the E figure was measured between the outer contours, and the height of the arresting grid was expressed as the height of a line unit (width of one line and one space.) Those figures corresponding to 6/6 vision (Snellen) were taken as having a value of 1.0 and used as units in the calculation of the relative heights.

(NOTE: Logarithms were taken, based on Voipio's model (1961). He refers to SLOAN (1951) who discusses Weber's law in connection with the argument for equal steps on a logarithmic scale. This is based on the assumption that the increase in size of the stimulus required to produce a just noticeable difference in discrimination is a constant fraction of the initial stimulus.

"It /

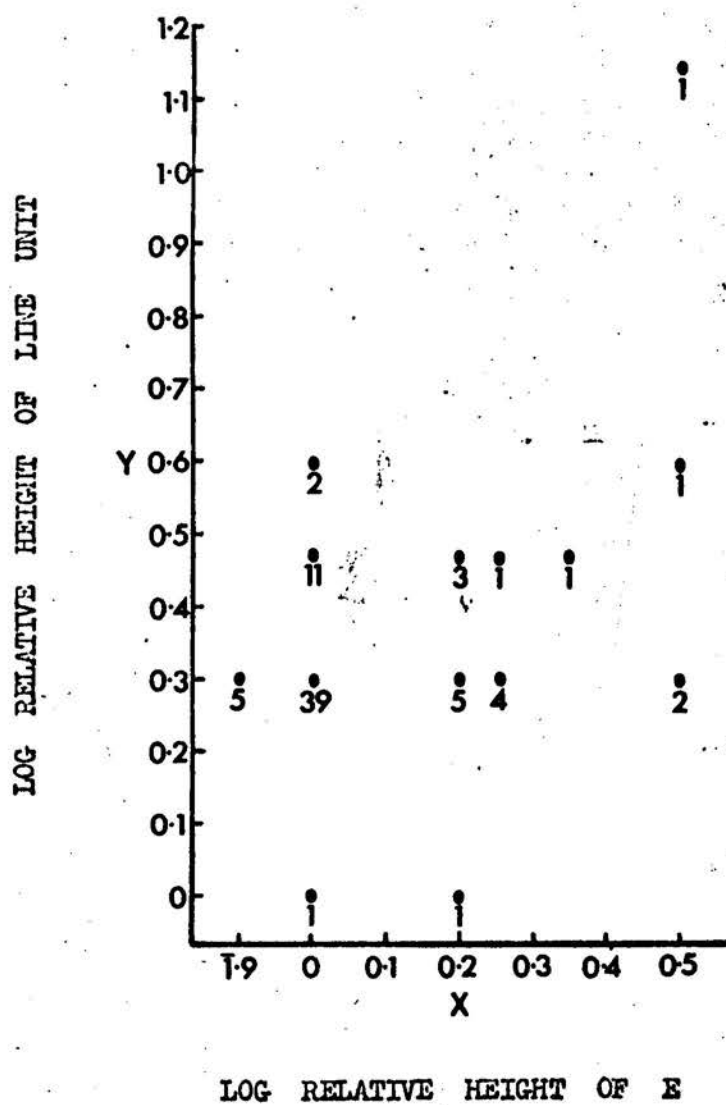


Fig. 40: Graph showing results obtained from the subjective and objective assessments (after Voipio, 1961).

"It is reasonable to suppose that it (Weber's law) may apply to the visual acuity of normal eyes whose errors of refraction have been corrected" - Sloan 1951 p.712).

Points corresponding to the pairs of observations for each eye tested were recorded on a graph (Fig.40) with X as abscissa representing the logs. of the relative heights of the E test, and Y as ordinate representing similar log. values of the line units of the arresting grid in the objective measurement. The numbers beside the points represent the frequency of cases in that category.

From this data, a scatter diagram for computing a Pearson's product moment correlation was prepared (for formula, see Appendix III p.330) The resulting correlation coefficient between the subjective and objective assessments was .22. The standard error of this value was .11 which places the correlation in the .05 region of significance ($.11 \times 1.96 = .21$). The probability associated with this coefficient is therefore at the .05 level. It is likely (by odds of 20 to 1) that the population ' \bar{r} ' will remain within the positive region, but the relationship between both tests in the sample is a slight one.

Discussion:

It can be seen that the quality of the optokinetic response /

response varied to quite a large extent throughout the sample. Only 35% of the eyes tested showed a wide, clear nystagmus, although in about 44% of the cases, a regular though small eye movement in response to the moving stimuli was observed. A small optokinetic nystagmus, however, made the task of observing the arrest of the movement very difficult. There did not appear to be any direct relationship between the clearness of the response and subjective visual acuity (Table 50).

The positive correlation obtained between the two methods of assessment, although significant at the .05 level, was nevertheless a small one. One reason for this is probably to be found in the narrow dispersion of acuities (the majority of children in the sample (75%) had visual acuities corresponding to 6/6 or 6/4 as measured subjectively by the E test.) It will be observed, however, that in spite of the low correlation coefficient, forty-nine of the sixty eyes with good visual acuity showed an arrested O.N. on the second grid (corresponding to 6/12 vision). The smallest grid which subtended 2' (black and white line) and which, according to WESTHEIMER (1965) - see p.241, thus had a Snellen equivalent of 6/6 vision (in contrast with Voipio's interpretation of the Optometric principle which resulted in a line unit whose total subtense was 5' /

5' corresponding to 6/6 vision), only succeeded in arresting O.N. in two eyes. Nevertheless, many of these children with good visual acuity (subjective) reported seeing the finest grid when it was presented with its grey background after the objective procedure. It must also be noted that since co-operation on the part of the children was good on the subjective test, it is probable that a fairly reliable assessment of the children's vision (as measured on this test) was being made.

The probable reason for this inadequacy of the smallest grid for arresting the O.N. was clear. The children showed great interest in the moving horses, which, it will be remembered, were designed in order to hold the child's attention. As a result, the O.N. proved difficult to arrest. There are two possible causes for this failure. Either the moving film assumed so strong an attraction that the arresting grid was a comparatively weak stimulus and in consequence required a much coarser grid than that which could be subjectively seen in order to arrest the 'reflex' movement; or, the stationary period of O.N. was so short as to prevent visual observation of the cessation. The resistance of this brief period to a visual analysis was aggravated in many instances by the small or irregular quality of the nystagmus. It seemed necessary to have a system of electrical /

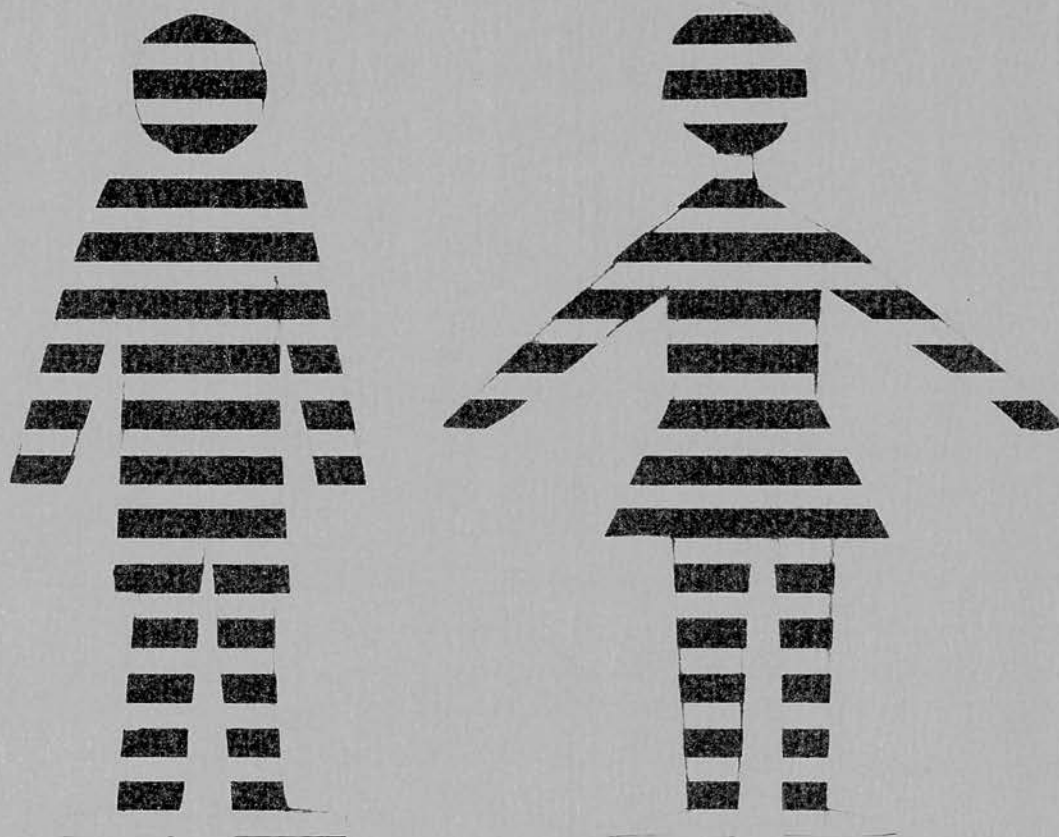


Fig. 41: Grid patterns for possible use in the arresting of optokinetic nystagmus in young children.

electrical recording of the response similar to that used successfully by Voipio (1966). (The difficulties, however, of applying any recording device to the young child, are many. These are not insurmountable, however.) Also, since the inducing stimuli required to be made more interesting for the young child, it is probable that a corresponding increase in the interest value of the arresting stimuli should also have been effected. A possibility for this increase might have been to make the over-all form of the grid depict, for example, the figure of a boy or a girl (see Fig.41). It will be recalled that only if the grid elements are resolvable will the total figure be seen, on account of the gray background.

All these factors tend to indicate that in young children this so-called 'objective' technique appears to be less objective than when used with adults. Factors like attention and interest must be considered as necessary conditions for the appearance of the 'reflex' movement. This method of assessment, however, does obviate the use of language and cognitive tasks such as matching procedures etc., so that in this sense, the method is much less subjective than traditional methods of testing. It appears possible that certain children who prove resistant to subjective assessment, might be validly tested for the presence of amblyopia by this type of objective technique.

4.7. Summary and Conclusions

The method of arresting O.N. has potential application in the detection of amblyopia at an early age, though it appears that greater tolerance in norms for objective acuity would have to be generally accepted. The stimulus needed to arrest O.N. appears to require greater dominance than a stimulus which simply requires to be seen. According to the findings in the present study, about 69% of the eyes tested showed a visual acuity of 6/12 as assessed objectively (it must be noted, however, that no intermediate grid between those corresponding to 6/6 and 6/12 was used), whereas 75% had vision of 6/6 or 6/4 as measured subjectively. The need for more refined methods of recording the arresting of O.N. is clear. Also, it is apparent that the 'objective' response depends to a large extent on attention and interest which tends to weaken its objectivity.

5. SUMMARY AND CONCLUSIONS

General dissatisfaction with existing methods of visual acuity testing of pre-school children prompted the present study. The central theme was as follows:- have children of this age group poor visual acuity compared with that of adults or are the findings concerning incomplete visual development in young children the result of unsatisfactory methods of assessment? Before an answer to this question could be given, it was first necessary to study the development of visual perception in children from three to five years of age. It was thought that a knowledge of the normal pattern of development of visual perception would provide an explanation for the generally poor performance of young children on visual acuity tests. The particular aspect of visual perception isolated in the present study was the perception of two-dimensional black and white forms (as found in most visual acuity tests). For this purpose, it was thought necessary to distinguish the growth pattern of the way in which children perceive their visual world, from the pattern of maturation of the visual system. The development of the naming response and of matching ability was studied over a wide range of stimuli. It was thereby recognised that any test of sensory function would require to be adjusted to the normal pattern of perceptual assimilation /

assimilation of the pre-school child.

In the study of the development of visual acuity (Form Sense) in the pre-school years, the effect was observed of increased motivation and more advantageous conditions of testing on the visual performance of the young child. From the results obtained it was concluded that pre-school children in general are far advanced in the development of the resolving power of the eye, the majority of them being capable of achieving adult standards.

The advantages of an objective method of assessment for this age group were recognised. The method attempted in this study was the arresting of Optokinetic Nystagmus without change in illumination. Limitations imposed on this method by fluctuations in attention in the young subjects and deficient means of testing, weakened its validity, but with certain suggested modifications to the apparatus, its possibilities as a valid means of assessment were established. Its use would be of particular importance in the assessment of children otherwise resistant to all subjective methods of visual acuity testing.

What, then, are the conclusions to be drawn from these studies towards improvement of visual acuity testing in pre-school children? It was affirmed that the characteristic features of the development of form perception in the pre-school child are important considerations /

considerations in the construction of a test of visual function. The most important finding from a review of previous studies in this area was that deficient performance of younger children on certain perceptual tasks which was thought previously to be due to a deficiency in the visual system, proved to have roots in other causes, principally in developmental features of the way in which visual perception takes place e.g. response to salient features (Wohlwill and Wiener), inadequate use of available information (VURPILLOT), and immaturity of intelligence (VERNON).

Whatever the reason for the child's inability to fully utilise visual information, there can be no doubt that information was available, mediated by a competent visual and perceptual mechanism. Thus the level of form perception required of a task is an important consideration in the assessment of sensory function based on this task.

In the present study it was recognised that the use of subjective tests in visual acuity testing was to introduce a cognitive factor (unavoidable in any subjective test). Naming and matching responses, in particular, demonstrated this. The pattern of development of matching and naming responses between the ages of three and five years were found to be as follows:-

1. /

1. Consistent types of errors were made on a matching-from-sample task involving geometrical shapes of 'similar' form. 'Similarity' was definable in these instances as pairs of forms having the same number of sides i.e. basic contour. In this case, height and area were negligible factors in 'similarity'. These errors were found to decrease with age.
2. Above-chance discriminations by younger children were obtained, which implied that other factors besides failure in discrimination were partly responsible for their high error scores. It was observed that high distractibility and impulsiveness were generally characteristic of their performance which would account for these types of error.
3. Pairs of pictorial representations provided a task which showed a similar increase in ability with age, although the level of success in the youngest age group, was much greater than success on the geometrical-shape task for the same age group. Increased interest in the pictorial material was thought to account for this improvement in the matching response.
4. Often the child's verbalisation of the difference between pairs after a match had been made, was helpful in an understanding of the choice made. Incorrect matches were sometimes found to be due, not to faulty discrimination /

discrimination, but to confusion resulting from instructions, etc.

5. A letter-matching task showed the same pattern of increased ability with age, although the ability was well advanced by the age of three years. A consistent type of error was again noted, particularly in the responses of the younger age group, viz. attention to the upper part of a letter often to the exclusion of inspection of the lower part, often resulting in confusion between letters of similar form e.g. E and F. There was also a marked tendency to confuse letters which were largely reversals of each other e.g. A and V.
6. Perception of the young child (about three years) appeared to be determined, not by the configural character of the stimulus, but rather by a tendency to respond to the over-all characteristics of the stimulus ('Syncretism'). This observation suggests that an assessment of the functional power of the visual system of the three year old will be invalidated to a large extent by a test which requires the distinct perception of parts. This finding is almost contrary to the principle on which most visual acuity tests are based (Snellen's Optometric Principle) where the perception of a whole form is believed to be determined by the discrete perception /

perception of its parts. It must be emphasised that the global nature of the young child's perception is in no way indicative of a deficient sensory apparatus for the discrimination of small details.

7. Simplification of a drawing can counteract the above-mentioned tendency to perceptual over-generalisation. Distinctive identifying features (defined empirically), however, must not be excluded from the simplified drawing to be used as a test of visual acuity. Ambiguous responses which might thereby arise would make the assessment of vision difficult.

The study of the development of visual acuity (Form Sense) showed that under favourable conditions viz. strong motivation, good rapport, proximity of test and tester, etc., visual acuity (defined in this instance as the ability to see small details of black against white in a certain orientation, and ability to resolve small separations between black lines) appeared to be well-developed in the pre-school child. Although Form Sense may not be developed fully in the sense that the characteristic ways of perceiving his world are such as to make the three year old's perception deficient (e.g. over-generalisation), yet his visual system is capable of making fine discriminations on an adult level. For under favourable conditions, the visual system of the average three /

three year old child has been found to be capable of resolving small details comparable with adult standards. How the child uses this information under ordinary conditions, however, is likely to be inferior to the use to which it is put by an older child. In this sense only, then, can Form Sense be said to develop in the pre-school years.

Apparent discrepancies between structure and function, therefore, which had been previously noted, were found to be spurious. The level of acuity reached in a particular test will be revealed only according to the nature of the test. A task which is within the comprehension and perceptual limits determined by the child's level of development, and which provides the child with sufficient motivation, should reveal the potentially fully-developed resolving power which has been shown to exist in the three year old child.

An 'objective' technique (the arresting of Optokinetic Nystagmus without change in illumination) was found to be less 'objective' when used with children. However, removal of language and other cognitive elements in such a test, is a great advance on many subjective tests. It appeared possible that certain children who had proved resistant to subjective methods of assessment might be validly tested for the presence of amblyopia using this type of technique.

BIBLIOGRAPHY

- ALBINI: Tavoli Ottimetriche, Naples 1885, (cit. by Duke-Elder, 1938, p.3900).
- ALLEN, H.F.: (1957) Testing of visual acuity in pre-school children. Norms, variables, and a new picture test. Pediatrics, 19: 1093.
- ALPERN, M.: Types of Movement, in The Eye ed. DAVSON, H., Vol.3. pp.63-151. New York and London: Academic Press.
- AMES, Louise B., LEARNED, Janet, METRAUX, Ruth, and WALKER, R.: (1953) Development of perception in the young child as observed in responses to the Rorschach test blots. J.genet. Psychol., 82: 183-204.
- BÁRÁNY, R.: (1921) Zur Klinik und Theorie des Eisenbahn-Nystagmus. Arch. Augenh., 88: 139.
- BENNETT, A.G.: (1965) Ophthalmic test types. Br.J. Physiol. Optics, 22: 238-271.
- BERENS, C.: (1938) Kindergarten visual acuity chart. Amer.J.Ophthal., 21: 667.
- BERENS, C.: (1958) Visual acuity and colour recognition tests for children. Amer. J.Ophthal., 46: 219.
- BLACKHURST, R.T., and RADKE, E.: (1966) Testing retarded children for defects in vision. Children, 13: 109-112.
- BOCK, R.H.: (1960) Amblyopia detection in the practice of pediatrics. Arch. Pediat., 77: 355-359.
- BOGUSLAVSKAYA, Z.M.: cit. by ZAPOROZHETS, 1965. pp.84-85.
- BOYNTON, R.M.: (1966) Vision in Experimental Methods and Instrumentation in Psychology, ed. SIDOWSKI, J.B. U.S.: McGraw-Hill Book Co.
- ter BRAAK, J.W.G.: (1936) Untersuchungen uber opto-kinetischen Nystagmus. Arch. neerl. de physiol., 21: 309.
- BROWN /

- BROWN, E.V.L.: (1938) Net average yearly change in refraction of atropinized eyes from birth to beyond middle life. Arch. Ophthalm., 19: 722.
- CARLEVARO, G.C., and OUIILLON, H.: (1960) Les troubles de la vue chez l'écologiste. Les Éditions Sociales Française.
- CHAVASSE, F.B.: (1939) Worth's SQUINT 7th ed. p.107. Philadelphia: Blakiston Co.
- COOK, E.B.: (1948) Comparative performance of commercial screening devices and far and near wall charts utilizing the same test targets. Naval Medical Research Lab., New London, Conn., (Rep. No. 5, Project NM-003-011(X-493)).
- COWAN, A.: (1928) Test letters which comply with the physiological requirements of a visual test object. Amer. J.Ophthalm., 11: 625-628.
- DAVENS, E.: (1966) The nationwide alert to pre-school vision screening. Sightsav. Rev., 36: 13-17.
- DAYTON, G.O., JANSEN, G., and JONES, Margaret: (1962) Visual acuity of infants measured by means of optokinetic nystagmus and oculogram. Investigative Ophthalm., 1: 414.
- DEERING, D.W.: (1958) Examination of the pre-school child. Am. Orthoptic J., 8: 117-128.
- DOLEŽALOVÁ, V.: (1964) Devices for ascertaining visual acuity in small children (transl. from Czech.). Cs. Oftalmologie, 20: 59-62.
- DOR, L.: (1920) Echelle optométrique universelle. Rev. gén. d'Optique, 34: 21.
- DUKE-ELDER, S.: (1932-1938) Textbook of Ophthalmology. Vol.I and Vol.IV, St. Louis: C.V. Mosby.
- DUKE-ELDER, S.: (1949) The Practice of Refraction. 5th ed. St. Louis: C.V.Mosby.
- DUKE-ELDER, S.: (1962) System of Ophthalmology. Vol.VII, London: Henry Kimpton.
- DWORETZKI, Gertrude: (1939) Le test de Rorschach et l'évolution de la perception. Arch. Psychol., Genève, 27: 233-396.

- EHLERS, H.: (1952) Clinical testing of visual acuity. Tr. Sec. Ophth. A.M.A. (cit. by ALLEN, 1957).
- ELKIND, D., KOEGLER, R.R., and GO, E.: (1964) Studies in perceptual development. II. Part-whole perception. Child Develop., 35: 81-90.
- EVANS, J.N.: (1919) Optotype for young children. Amer. J. Ophthal., 2: 425.
- EVANS, J.N.: (1946) A visual test for infants. Amer. J. Ophthal., 29: 73-75.
- FANTZ, R.L.: (1958) Pattern vision in young infants. Psychol. Rec. 8: 43-47.
- FANTZ, R.L., and ORDY, J.M.: (1959) A visual acuity test for infants under six months of age. Psychol. Rec., 9: 159-164.
- FANTZ, R.L., ORDY, J.M., and UDELF, M.S.: (1962) Maturation of pattern vision in infants during the first six months. J.Comp.Physiol.Psychol., 55: 907-917.
- FFOOKS, O.O.F.: (1965a) The single optotype. Brit. Orthoptic J., 22: 95-97.
- FFOOKS, O.O.F.: (1965b) The symbol test. A new test for visual acuity. Brit. Orthoptic J., 22: 98-100.
- FINK, W.H.: (1959) Testing visual acuity of the pre-school child. Minnesota Med., 42: 23-24.
- FREUDENBERG, K., MEYERRATKEN, E., and PAHLITZSCH.: (1960) A. v. Graef's Arch. Ophth. 162: 318. (cit. by PEARSON, 1966).
- GELLERMANN, L.W.: (1933) J.Genet. Psychol., 42: 3 and 28. (cit. by VERNON, 1937).
- GESELL, A.: (1949) Developmental aspect of child vision. J.Pediatrics, 35: 310.
- GHENT, L.: (1963) Stimulus orientation as a factor in recognition of form. Paper read at Eastern Psychol. Assn. New York, April.
- GIBSON, J.J.: (1950) The Perception of the Visual World. Boston: Houghton Mifflin.
- GIBSON /

- GIBSON, J.J.: (1951) What is form? Psychol. Rev., 58: 403-412.
- GIBSON, J.J., and GIBSON, Eleanor J.: (1955) Perceptual learning: differentiation or enrichment? Psychol. Rev., 62: 32-41.
- GIBSON, Eleanor J., GIBSON, J.J., PICK, A.D., and OSSER, H.: (1962) A developmental study of the discrimination of letter-like forms. J.Comp. Physiol. Psychol., 55: 897-906.
- GOLDMANN, H.: (1943) Objektive Sehschärfenbestimmung. Ophthalmologica, 105: 240.
- GORMAN, J.J., COGAN, D.G., and GELLIS, S.S.: (1957) An apparatus for grading the visual acuity of infants on the basis of optokinetic nystagmus. Pediatrics, 19: 1088-1092.
- GUILFORD, J.P.: (1956) Fundamental Statistics in Psychology and Education, 3rd ed. U.S.: McGraw-Hill Book Co., Inc.
- GUNTHER, G.: (1948) Ein Gerät zur objektiven Prüfung der zentralen Sehschärfe. A.V. Graefe's Arch. Ophth., 148: 430.
- HATFIELD, E.M.: (1966) A year's record of pre-school vision screening. Sightsav. Rev., 36: 18-22.
- HEBB, D.O.: (1961) Organization of Behaviour. New York: Science Editions Inc.
- HECHT, S., and MINTZ, E.: (1939) The visibility of single lines at various illuminations and the retinal basis of visual resolution. J.gen. Physiol., 22: 593-612.
- HEIMANN, E.: (1905) Sehprobentafel für Kinder.
- von HELMHOLTZ, H.: (1866) (cit. by DUKE-ELDER, 1962), Physiol. Optik., Leipzig, 1,
- HERSHENSON, M.: (1964) Visual discrimination in the human new-born. J. Comp. Physiol. Psychol., 58: 270-276.
- HILL, K., and STOCKS, J.F.: (1962) Assessment of vision of the preliterate child. J. Maine Med. Ass., 53: 30-33.
- HIRSCH /

- HIRSCH, M.J.: (1964) The Refraction of Children, in Vision of Children ed. HIRSCH and WICK. Philadelphia: Chilton. pp.145-172.
- HOFSTAETTER, P.R.: (1954) The changing composition of 'intelligence': a study of the t-technique. J.Genet. Psychol., 85: 159-164.
- HOOKE: (1705) (cit. by DUKE-ELDER, 1932, Vol.I, p.919).
- HORSTEN, G.P.M., and WINKELMAN, J.E.: (1962) Electrical activity of the retina in relation to histological differentiation in infants born prematurely and at full-term. Vision Research, 2: 269-276.
- JONES, L.V.: (1949) A factor analysis of the Stanford-Binet at four age levels. Psychometrika, 14: 299-331.
- JONKERS, G.H.: (1958) The examination of the visual acuity of children. Ophthalmologica (Basel), 136: 140.
- KAIVONEN, M., and KOSKENOJA, M.: (1963) Visual screening for children aged four years and preliminary experience from its application in practice (a preliminary report). Acta Ophthalmologica, 41: 785-786.
- KENNEY, A.H.: (1951) Chronology of Ophthalmic Development. Springfield, Ill.: Charles C. Thomas.
- KELLOG, R. et al.: (1965) Form-similarity between phosphenes of adults and pre-school children's scribbles. Nature, 208: 1129-1130.
- KERPELMAN, L.C., and POLLOCK, R.H.: (1964) Developmental changes in the location of form discrimination cues. Percept. Mot. Skills, 19: 375-382.
- KESTENBAUM, A.: (1930) Zur Klinik des optokinetischen Nystagmus. A. v. Graefe's Arch. Ophtho., 124: 339.
- KESTENBAUM, A.: (1948) Arch. d'Ophthal., 8: 624. (cit. by KESTENBAUM, 1957).
- KESTENBAUM, A.: (1957) Nystagmus, review of the literature 1946-1954. Advances Ophth., 7: 221-286.
- KITTREDGE, Edwina, and CUNNINGHAM, Florence: (1965) Pre-kindergarten vision screening in Yonkers public schools. J. Sch. Health, 25: 278-280.

- de ALLEN, A.: Acta Oto-Laryng. Suppl.78, 8, 1948/49
(cit. by KESTENBAUM 1957).
- KORNBLATT, S., and SAFFERSTEIN, D.: Amer.J.Optom.,
40:205, 1963 (cit. by PEARSON, 1966).
- AUHNHART: (1959) The objective proof of the vision
of amblyopes. Klin.Mbl.Augenheilk, 134: 117.
- de LAET, H.A., and SZUCS, S.: (1959) Bull.Soc.
Belge.Ophtal. 120: 527 (cit. by PEARSON, 1966).
- LAKOWSKI, R., and ASPINALL, P.: (1968) Static per-
imetry in children. Unpublished paper.
- LANDOLT, E.: (1888) S.franz.O., 6:213. (cit. by DUKE-
ELDER, 1938, Vol.2. p.1203).
- LANDOLT, E.: (1889) Un tableau d'objets types pour
la détermination de l'acuité visuelle et de
l'astigmatisme. Bull.Mém.Soc.fr.Ophtalmologie.
157-160.
- LANDOLT, E.: (1904) cit. from BRUCKNER, A.: Kurzes
Handbuch der Ophthalmologie. Berlin: Springer.
Vol.II, p.926.
- LEWIS, M., KAGAN, J., and KALAFAT, J.: (1966) Patterns
of fixation in the young infant. Child Develop.,
37: 331-341.
- LING, Bing-Chung: (1941) Form discrimination as a
learning cue in infants. Comp.psychol.Monogr.,
17.
- LINE, W.: (1931) Brit.J.Psychol.Monog. No.15. (cit.
by VERNON, 1937).
- LINKSZ, A.: (1952) Physiology of Vision. Vol.II, p.242.
New York: Grune and Stratton.
- LÖHLEIN, W., and GEBB, H.: (1909-1910) Zur Frage der
Sehschärffenbestimmung. Arch.Augenh., 65: 69-97.
- LÜSCHER, A.J.: (1955) Ophthalmologica, 129: 116,
(cit. by PEARSON, 1966).
- McCALLIE, J.M.: (1909) Kindergarten acuity test.
Chicago: P.H.Stoelting Co.
- McDERMOTT /

- McDERMOTT, Anne: (1965) Towards a definition of visual acuity in Pre-School Children. Unpublished undergraduate thesis.
- McNemar, Q.: (1942) The Revision of the Stanford-Binet Scale. Boston: Houghton.
- MANN, Ida: (1949) in The Eye and its Diseases 2nd ed., ed.: BERENS, C. Pa., Philadelphia: W.B.Saunders Co.
- MEILI, R.: (1931) Les perceptions des enfants et la psychologie de la Gestalt. Arch.Psychol.Geneve, 23: 25-44.
- MEILI-DWORETZKI, Gertrude: (1956) The Development of Perception in the Rorschach in Developments in the Rorschach Technique, ed. KLOPFER, B., pp.108-176, World Book.
- MONJÉ, M.: (1958) Der Lichtsinn - Physiologie des Auges in Der Augenarzt ed. VELHAGEN, K., Vol.I, Leipzig, Thieme.
- MORGAN, C.T., and STELLAR, E.: (1950) Physiological Psychology. New York: McGraw-Hill Book Co.
- MORGAN, LLOYD, A., CRAWFORD, J.S., PASHBY, T.J., and GABY, J.R.: (1952) A survey of methods used to reveal eye defects in school children. Canad.M.A.J. 67: 29-34.
- MORRISON, Jeanette B.: (1966) Comparison of screening types used in vision-screening of young children. Med.Off. 115(4): 45-46.
- MORRISON, L.C.: (1963) Psycho-optical movements of the eyes. Part I: Brit.J.Physiol.Opt. 20: 99-112; Part II: ibid. pp.142-159.
- MUNN, N.L., and STIENING, B.R.: (1931) J.Genet.Psychol. 39: 73 (cit. by VERNON, 1937).
- van NOORDEN, G.K.: (1967) Classification of amblyopia. Amer.J.Ophthal., 63: 238-243.
- OHM, J.: (1922) Die Klinische Bedeutung des optischen Drenystagmus. Klin.Mbl.Augenheilk, 68: 323.
- ORDY, J.M., LATANICK, A., SAMORAJSKI, T., and MASSOPUST, L.C.Jr.: (1964) Visual acuity in newborn primate infants. Proc.Soc.Exp.Biol.Med., 115:677-680.
- ØSTERBERG /

- ØSTERBERG, G.: (1936) A sight-test chart for children. Acta Ophthalmologica, 14: 397.
- ØSTERBERG, G.: (1965) A Danish pictorial sight-test chart. Amer.J.Ophth., 59: 1120-1123.
- PARR, J.C.: (1962) Vision in the young child. New Zeal.Med.J. 61: 33-38.
- PASIK, P., PASIK, T., and KRIEGER, H.P.: (1959) Effects of central lesions upon optokinetic nystagmus in monkeys. J.Neurophysiol., 22: 297-304.
- PEARSON, R.M.: (1966) The objective determination of vision and visual acuity. Brit.J.Physiol.Optics. 23: 107-128.
- PECKHAM, R.H.: (1932-33) Visual discrimination in pre-school children. Child Develop., 3-4: 292-297.
- PETERS, H.B., BLUM, H.L., and BETTMAN, J.W.: (1959) Vision screening for elementary schools; the Orinda Study. Univ. of California Press, Berkeley.
- PIAGET, J., and MORF, A.: Les isomorphismes partiels entre les structures logiques et les structures perceptives. In Études d'Épistémologie Génétique, ed.: PIAGET, J.: (1958) Presses Universitaires de France, Vol.VI, pp.51-116.
- PIRENNE, M.H.: (1962) Visual Acuity in The Eye, ed. DAVSON, H. Vol.2, pp.175-195. New York and London: Academic Press.
- PITMAN, E.J.G.: (1937) Significance tests which may be applied to samples from any populations. Supplement to J.R.Statist.Soc., 4: 119-130.
- PUGMIRE, Gertrude E., and SHERIDAN, Mary D.: Med.Off., 43: 133, 1930 (cit. by SHERIDAN, 1960).
- RABETGE, Gisela.: (1965) Sehprüfungen beim Kleinkind. Buch.Augenarzt., 45: 9-16.
- RABIDEAU, G.F.: (1955) Differences in visual acuity measurements obtained with different types of targets. Psychol.Monog., 69, No.10: 1-12.
- REINECKE, R.D.: (1959) Objective and subjective testing of visual acuity in amblyopic patients. Amer.Orthopt.J. 9: 93-95.
- REINECKE /

REINECKE, R.D.: (1961) Review of optokinetic nystagmus from 1954-1960. Arch.Ophthal., 65: 609-615.

REINECKE, R.D., and COGAN, D.G.: (1958) Standardisation of objective visual acuity measurements: Optokinetic nystagmus vs. Snellen acuity. A.M.A. Arch. Ophthal., 60: 418-421.

RYBA: Optotype. (cit. by DOLEZALOVA, 1964).

RYCHENER, R.O.: (1958) Vision tests in infants and young children. Pediat. Clin. N.Amer., 231-238, Feb.

SAVITZ, R.A., REED, R.B., and VALADIAN, Isabelle: (1964) Vision Screening of the pre-school child. Washington, D.C.: U.S.Dept. of Health, Education and Welfare.

SAVITZ, R.A., and VALADIAN, Isabelle: (1968) Vision testing of infants in a Child Health Clinic and at home. Amer.J.Publ.Health, 58: 95-100.

SCALA, N.P., and SPIEGEL, E.A.: (1938) The mechanism of optokinetic nystagmus. Trans.Amer.Acad.Ophthal., 43: 277-299.

SCALA, N.P., and SPIEGEL, E.A.: (1940) Subcortical (passive) optokinetic nystagmus in lesions of mid-brain and of vestibular nuclei. Confinia neurol. 3: 53.

SCHÖBER, G., and SCHÖBER, Ada: (1919) Über Bilderkennungs- und Unterscheidungsfähigkeit bei kleinen Kindern. Beih.Z.angew.Psychol., 19: 94-137.

SCHWARTING, B.H.: (1954) Testing infants vision (an apparatus). Amer.J.Ophthal., 38: 714.

SEGGERS, J.E.: (1926) J. de Psychol., 23: 608 and 723, (cit. by VERNON, 1937).

SELINKA, R.: (1939) Der Übergang von der ganzheitlichen zur analytischen Auffassung im Kindesalter. Z.pädag. Psychol., 40: 256-278.

SHERIDAN, Mary D.: (1960a) Manual for the Stycar Vision Test. Distributed by The National Foundation for Educational Research in England and Wales, London.

SHERIDAN /

- SHERIDAN, Mary D.: (1960b) Vision screening of very young or handicapped children. British Med.J., 5196: 453-456.
- SIEGEL, S.: (1956) Nonparametric Statistics: For the Behavioural Sciences. McGraw-Hill Book Co., Inc.
- SJOGREN, H.: (1939) A new series of tables for testing acuity in children. Acta Ophthal., 17: 67.
- SLATAPER, F.J.: (1950) Age norms of refraction and vision. Arch.Ophthal., 43: 466-481.
- SLOAN, L.L.: (1951) Measurement of visual acuity: a critical review. Arch.Ophthal., 45: 704-725.
- SMITH, H.C.: (1937) Imbalance of vertically acting extra-ocular muscles. Arch.Ophthal., 4: 533.
- SNELLEN, H.: (1864) Test-Types for the Determination of the Acuteness of Vision (2nd ed.), Printed by P.W.Van de Weijer, Utrecht.
- SOKHINA: Cit. by ZAPOROZHETS, 1965, pp.91-92.
- SORSBY, A., BENJAMIN, B., and SHERIDAN, M.: (1961) Refraction and its Components during the Growth of the Eye from the Age of Three. London: H.M.Stat-ionery Office. Med. Research Council Spec.Report Series, No.301.
- SPIEGEL, E.A., and SCALA, N.P.: (1944) Vertical nystagmus produced by peripheral labyrinthine lesions. Arch. Otolaryng., 40: 160-163.
- SPIEGEL, E.A., and SOMMER, I.: (1944) Neurology of the Eye, Ear, Nose, and Throat. New York: Grune and Stratton.
- STIRNIMANN, F.: (1944) Über das Farbenempfinden Neugeborener. Ann. Paedia., 163: 1-25.
- STOFFT, P.: (1961) Essai d'utilization de la stimulation lumineuse intermittente pour l'appréciation du développement de la fonction visuelle chez le nourrisson. Ann. d'oculistique, 194: 133-152.
- TANNER, J.M.: (1961) Education and Physical Growth. London: Univ. of London Press, Ltd.
- TAUBENHAUS /

- TAUBENHAUS, L.J., and JACKSON, Anne A.: (1965) Vision screening of pre-school children. Sightsav. Rev., 35: 100-104.
- TERMAN, L.M., and MERRILL, Maud A.: (1960) Stanford-Binet Intelligence Scale, Manual for the Third Edition, Form L-M. London: George G.Harrap & Co., Ltd.
- van der TORREN, J.: (1907) Über das Auffassungs- und Unterscheidungsvermögen für optische Bilder bei Kindern. Z. angew. Psychol., 1: 189-232.
- VENGER, L.A.: Cit. by ZAPOROZHETS, 1965, pp.83-84.
- VERNON, M.D.: (1937) Visual Perception. Cambridge University Press.
- VOIPIO, H.: (1961) The Objective Measurement of Visual Acuity by Arresting Optokinetic Nystagmus Without Change in Illumination. Supplement 66, to Acta Ophthalmologica.
- VOIPIO, H., and HYVARINEN, L.: (1966) Objective measurement of visual acuity by Arrestovisography. Arch.Ophthal., 75: 799-802.
- VURPILOT, Eliane: (1965-66) A study of the development of scanning strategies of children in judging similarity. Reported in Harvard University: The Centre for Cognitive Studies. Sixth Annual Report, pp.9-11.
- WAGNER, H.N. Jr.: (1950) Objective testing of vision with use of the galvanic skin response. A.M.A.Arch. Ophthal., 43: 529.
- WALSH, F.B.: (1957) Clinical Neuro-Ophthalmology. Baltimore, Williams and Wilkins.
- WANG, Chih-Ching: (1965) Movement of the eye and development of visual object perception in children of pre-school age. (Transl. from Chinese). Acta Psychologica Sinica, 32(3): 259-264.
- WEISS: (1897) Cit. by SORSBY et al. 1961.
- WESTHEIMER, G.: (1965) Visual Acuity in Annual Review of Psychology. 16: 359-381.
- WEYMOUTH /

- WEYMOUTH, F.W.: (1964) Visual Acuity in Children, in Vision of Children ed.: HIRSCH, M.J. and WICK, R.E. pp.119-144. Philadelphia: Chilton.
- WOHLWILL, J.F.: (1960) Developmental studies in perception. Psychol. Bull., 57: 249-288.
- WOHLWILL, J.F., and WIENER, M.: (1964) Discrimination of form orientation in young children. Child Develop., 35: 1113-1125.
- WOLFFBERG, L.: (1914) Bilderbuch zur Sehsscharfe-Pruung von Kindern und Analphabeten. 2nd ed. Leipzig, Engelmann.
- WOLIN, L.R., and DILLMAN, Arline: (1964) Objective measurement of visual acuity. Arch.Ophthal., 71: 822-826.
- WORTH, C.: (1896), (cit. by DUKE-ELDER, 1938, Vol.2, p.1203).
- ZAPORozHETS, A.V.: (1965) The development of perception in the pre-school child. In European Research in Cognitive Development, ed.: MUSSEN, P.H. Mono-graphs of the Society for Research in Child Development, Vol.30, No.2. Chicago.
- ZINCHENKO, V.P., and RUZSKAYA, A.G.: Cit. by ZAPORozHETS, 1965, pp.85-88.
- ZIOBROWSKI, S.: (1959) Optotype. Klin.oczna, 29(4): 417-426.
- ZUCKERMAN, C.B., and ROCK, I.: (1957) A reappraisal of the roles of past experience and innate organizing processes in visual perception. Psychol. Bull., 54: 269-296.
- The Eye in Childhood, eds.: The Ophthalmic Staff of the Hospital for Sick Children, Toronto. Year Book Medical Publishers, Inc. Chicago.

APPENDIX ITHE OPTOMETRIC PRINCIPLE.

In 1705, HOOKE observed that the separation of two stars could be perceived if this separation subtended one minute of arc at the nodal point of the eye. His observations were confirmed by many subsequent investigators in studies of the minimum separable; but later findings demonstrated that the smallest point which could be seen - the minimum visible - was of much smaller value than the minimum perception of separation. For example, HECHT and MINTZ (1939) using a single dark line against a light background found that the smallest which could be seen subtended an angle of 0.5 seconds. It can be seen however, that the two tasks differ in complexity and it is generally agreed that the expected values for the minimum separable should be greater than those for a minimum visible task.

The beginnings of present-day testing, however, can be seen in the work of Herman SNELLEN. In 1862, he published the first copies of his standardised test types based on his investigations on the minimum visible. Corroborating Hooke's unstandardised results, Snellen stated that a normal eye could perceive the separation between two lines which subtended one minute of arc at the /

the nodal point.

In 1864, the second edition of the test types appeared with the following preface...

"The 'Test Types for the determination of the acuteness of vision' have been tried at the army Medical School of England, and found to answer so well for the examination of the visual fitness of the recruits, that the Professor of Military Surgery, Dep. Insp. Gen. J. Longmore applied to the War-department to have them distributed among the medical officers of the British army."

This edition contained the following statements...

"The smallest angle, at which objects of known size and known form can be distinguished determines the degree of acuteness of vision.

To determine the smallest visual angle we measure the utmost distance at which objects of definite size can be recognised.

A visual angle and corresponding distance being taken as unit of measure, the proportion between such distance and that at which the object is actually seen, expresses the acuteness of vision.

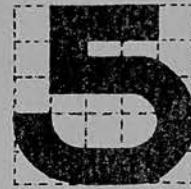
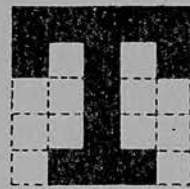
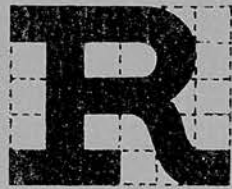
We take as unit for comparison the recognition of letters seen at an angle of five minutes.

We have adapted as proper objects square letters, whose limbs have a diameter equal to one fifth of the letter's height. Such letters are clearly distinguished by a normal eye at an angle of five minutes. As the limbs and subdivisions of the letter just measure one fifth of their height, they present themselves at an angle of one minute; for instance, our letter C shows an opening, as compared with the O, of one minute visual angle.

In testing accuracy of vision, we accept perfect recognition and not uncertain perception of the letters.

Reading /

L.



XL.

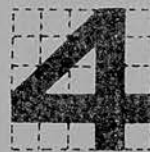


Fig. 42: Original Snellen letters and illiterate figures (1862).

Reading cannot be completely identified with the recognition of our isolated letters; reading being easier in some respects because some letters can be guessed from their conjunction with others; and more difficult in other respects because the letters of words as they are usually printed, are huddled closely together.

Square figures constructed in the proportion of one to five may be considered equal to our test-types. For people who cannot read, there are added to the test-types figures whose form can be promptly stated, as: square, circle, open square, cross, chequered pattern, vertical and horizontal lines."

(see Fig.42 for original Snellen letters and illiterate figures.)

Snellen's original optotypes were based on a typeface known as 'Egyptian Paragon' with ornamental cross-strokes or 'serifs' (BENNETT 1965). As was stated, a framework composed of unit squares (generally 5 x 5 units) was used for the construction of the letters, so that the over-all subtense of a letter was 5' of arc, and the thickness of the component limbs and spaces subtended an angle of 1'. Some of Snellen's letters, however, infringed this convention. Also, it is implicit in Snellen's thinking that in order to perceive, for example, a letter E, the component parts must be seen as distinct and separated by white inter-spaces. Perceptual processes, however, do not appear to be determined by the simple optical principle, and the recognition of a letter need not depend on the visual separation /

separation of parts - cf. differing legibilities of test letters. This fact has led to research into which letters best serve as items for acuity testing, but the problem of reading facility and of aptitude for inference of different subjects makes the question a difficult one.

In spite of these drawbacks, however, Snellen's findings form the basic convention accepted by most optometrists; and it would appear that in the testing of adults at least, this convention represents a valid means of assessment. Vision as determined by the optometric principle, is expressed by the distance at which the letters are recognised (d) divided by the distance at which they appear at an angle of five minutes of arc (D).

$$\text{Thus, } V = \frac{d}{D} .$$

If D and d are found to be equal, then vision is 6/6, and this is normal visual acuity.

When the need for the early testing of children became apparent, it was natural that pictures should have been chosen as test objects - the spontaneous interest shown in pictures by children seemed an invaluable asset to the test constructor. Snellen's optometric principle, however, which placed great emphasis on the accuracy of the size of components, had somehow to be included in a test for children if such a test was to /

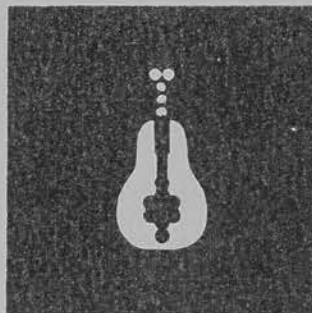
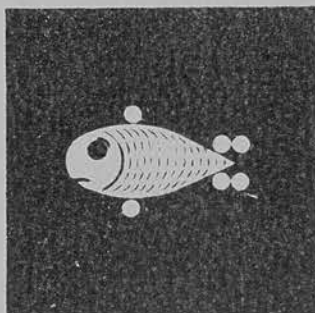
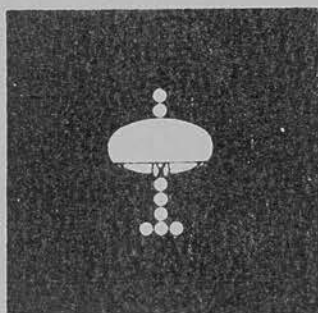
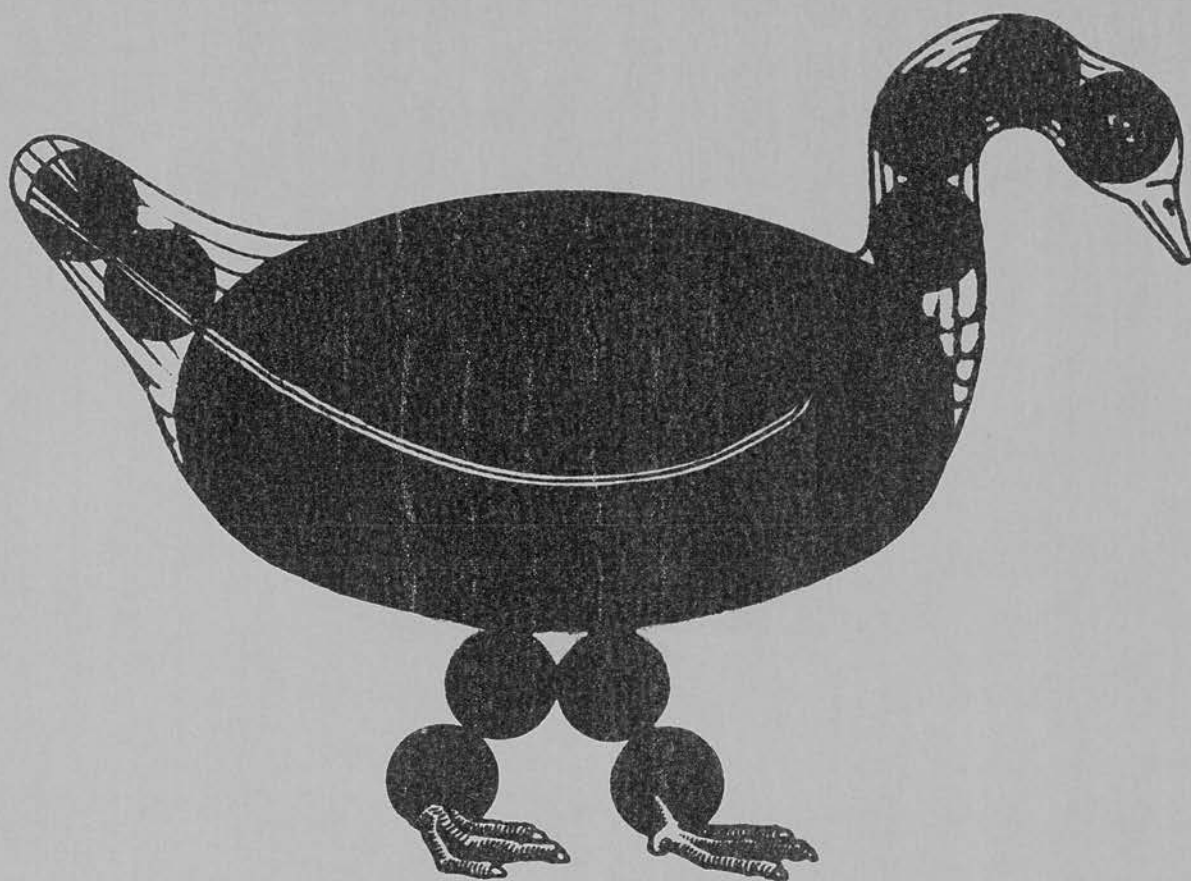


Fig. 43: Wolffberg's Pictorial Chart for children (1892).

to be considered comparable to the adult test-types. It was this principle that caused the controversy concerning construction of a test for children in the early days of testing, and advocates of each choice are still to be found. ØSTERBERG (1936) gives an interesting account for this dispute.

WOLFFBERG, as early as 1892, constructed a pictorial chart for children. Thirty-one different figures were designed in the following way:- geometric shapes e.g., circle, rectangle, etc., were used as a basis to which were added round dots of equal size in such a way as to represent a common object (Fig.43) - (this will be described fully in the next section p.289.) Since it was not the basic shape which determined the object, but rather the particular placement or combination of the smaller round dots ('FLACHENPUNKTE'), it was the latter elements which were calculated to be seen at the 1' visual angle. Thus the optometric principle was adhered to but, in this case it would seem, often at the expense of realistic representation. This difficulty, as will be seen later, is the problem inherent in all rigid interpretations of the optometric principle. Snellen found that certain letters were resistant to treatment by his convention; the suitability of complex pictures for the optometric treatment /

treatment is even more doubtful. For instance, LANDOLT (1904) remarked on the ...

"so-called sight tests for children, consisting of pictures ... such hieroglyphs are far too incompatible with optometric principles; they cannot even be compared with normal tests ..."

LÖHLEIN (1910) reiterating Landolt's words, denied the possibility of constructing a reliable picture chart on the Snellen principle. Furthermore, he found that some of Wolffberg's test items were recognisable at twice the designed distance. Lohlein then postulated good 'ERKENNUNGSKONSTANZ' or constancy of recognition of items as a criterion for inclusion in a sight-test chart. A measure of this quality was obtained by presenting a number of emmetropes with an assortment of pictures at a great distance. As this distance was gradually lessened, some objects were recognised by the majority of the subjects at approximately the same distance. By selecting those items recognised in this way by emmetropic children of different age groups, Lohlein was able to produce a sight-test chart which had validity for a given age group. Thus 'Erkennungskonstanz' was empirically determined. ØSTERBERG (1936), however, when testing Lohlein's claims, discovered that some objects were recognised more easily than others, and that constancy could /

could differ between the sexes. We can conclude that Löhlein's claims of 'constancy of recognition' for certain objects had validity only for his particular group of subjects and his period of testing. Nonetheless, his work draws attention to an assumption crucial to the optometric principle as used by Snellen viz. that normal acuity should be defined in terms of the 1' visual angle separation. Snellen had been justified in thus defining acuity, for his investigations had yielded this value as a convenient norm. But how generalisable were his findings, and could they be used without further investigation for other age groups? Snellen's findings while valid for his subjects, had an unfortunate consequence, namely, the conferring of an ontological status on visual acuity, from the results of one visual acuity test. It is as a result of this that Østerberg says ...

"... the optometric principle cannot possibly be dropped in the construction of pictures aiming at testing the visual acuity of children."

The question of whether or not separation is even a testable entity in the perception of the very young child seems never to have been asked by those adherents to the optometric principle which is a 'law' drawn only from limited empirical data. There seems no reason why other norms should not exist for the pre-school child /

child. Even accepting this principle as established, only as long as it is used in the simplest form e.g., Landolt's C test, can the claim to an ontological status for visual acuity (regarded as the potential power of the eye for discrimination) reasonably be made. As soon as letters are introduced, the problem becomes a perceptual one, and the other assumption implicit in Snellen's work viz. that the perception of the whole figure is equal to the sum of the perceptions of its parts, is quite unfounded.

Hence, the anxiety over the necessity of the optometric principle when designing a test for children, seems a little misplaced. On the other hand, if the vision of children should be described in adult terms rather than in terms of the average vision for children of a certain age, then the principle must be considered.

APPENDIX IIHISTORICAL REVIEW OF PRE-SCHOOL VISUAL ACUITY TESTS.

The origins of recorded visual acuity are probably to be found in the work of the scientist Robert HOOKE, who in 1705, observed that the separation of two stars could be appreciated if this separation subtended one minute of arc at the nodal point of the eye. In 1862, the first test-types were published. They were those of Herman SNELLEN, and the same value of minimal separation as found by Hooke was used as the basis for their construction. The test consisted of rows of letters which had to be read at a given distance (see The Optometric Principle Appendix I, p.279).

The testing of young children presented a different problem. The child required to be sufficiently interested in the task in order to produce results directly related to his visual ability and not wholly dependent on other factors such as attention, intelligence, etc. Since the Snellen letters were not practicable for pre-literate children (apart from the E test - a later development of the Snellen principle by ALBINI 1885), another form of test object had to be found. Another important consideration was the additional limitation of the responses that young children were /

were capable of giving. It was therefore not surprising that pictures were frequently chosen by those concerned with the problem of testing this age group. Snellen's principle of the minimum separable (the optometric principle) being the generally accepted basis of testing at the time (as indeed it still is), was naturally the framework in which the development of child-testing took place.

A departure from the difficulties of the Snellen letters caused by their cognitive component, was seen in the work of LANDOLT (1888). The optometric principle was adhered to but a constant pattern was now used (similar to that used by Albinus in 1885). A ring with a gap in it which subtended an angle of 1' at the prescribed distance (in this case five metres), was shown to the subject who was then required to indicate in which segment of the ring the gap lay. This test was approved as a standard international test by the Congress held in Naples in 1909, and again at Amsterdam in 1929. This test was particularly useful for illiterates, and for this reason was also deemed suitable for use in the testing of pre-literate children. It must be noted, however, that 'pre-literate' and 'illiterate' are quite different states, and that it is incorrect to apply tests to pre-literate children which have been designed for /

for use with illiterate adults. The test has been reported as boring to the young child, whose sense of direction is, in addition, easily confused. A much more important criticism, however, has been directed by DUKE-ELDER (1938) viz. that the gap is probably recognised by the increased illumination in that position before its form is appreciated, so that a higher value of form discrimination is obtained than in fact exists. Also, SHERIDAN (1960) has made a general objection to tests which use a constant configuration as items. She stated that the child's performance over a wide range of perceptual configurations should be assessed.

As has already been mentioned (p.283), the first pictorial chart was designed in 1892 by WOLFFBERG, and has been revised and improved several times since. He accepted the rationale of the optometric principle and constructed his pictures on this basis, claiming perfect correspondence between his work and the Snellen letter chart. The response required of the child was one of recognition. The 1914 edition of the chart contained thirty-one different figures all constructed as follows:- a given basic geometric shape was used as the foundation to which was added an arrangement of round dots of equal size, to result in a representation of a common object, animal /

animal, etc. Since, it was supposed, the particular grouping of these dots was the critical factor in the identification of the picture, the dots were the elements which were calculated to be seen at the 1' visual angle (see Fig. 43). These 'Flächenpunkte' or dot elements were thus supposed to be comparable with the components of the Snellen letters. Landolt, however, in 1904, rejected the use of picture charts as being far too incompatible with the optometric principle and thus unable to be compared with 'normal tests'. Also LÖHLEIN (1910) found by experimentation that the theoretical principle in the design of Wolffberg's pictures was not borne out in practice. He found, for example, that some of the figures were recognisable at twice the distance for which they were designed. It is also very obvious from inspection of the pictures that realistic representation had been sacrificed to the constraints of the so-called optometric principle. Thus it would appear that as early as this after the original work, Snellen's attempts to define the minimum separable had already been abstracted without any reference to the change in the experimental conditions viz. the fact that, now, children were the test subjects, and also that the visual two-point limen would now have little or nothing to do with whether or not the whole stimulus /

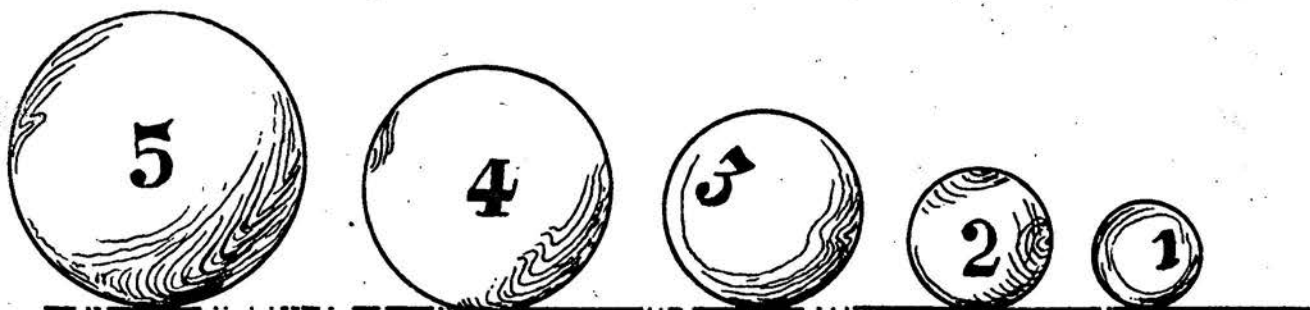


Fig. 44: Worth's Ivory Ball test (1896).

stimulus would be recognised and named by the child. (Snellen letters, of course, are subject to the same criticism that the perception of the whole letter will not necessarily be solely a function of the visual separation of parts.)

In 1896, WORTH referred to another method of measurement of children's vision viz. the Worth ivory ball test (see Fig.44). This was a departure from the traditional black and white charts, although the optometric principle was still evident in the choice of sizes of balls used, and in the fact that they were whitish and designed to be thrown onto a dark floor. The balls were of the following sizes : $1\frac{1}{2}$ " diameter, $1\frac{1}{4}$ ", 1", $\frac{3}{4}$ ", and $\frac{1}{2}$ ". The purpose of the test was to evaluate the visual acuity of children too young to co-operate in the more conventional subjective tests. (PEARSON, (1966), perhaps incorrectly, classifies this test as an objective method. The method does depend a great deal on the co-operation of the child, but it certainly requires a less subjective response than the naming response required of most picture charts.) The child was first allowed to handle the balls for a few moments with both eyes open. One eye was then occluded, and the tester spun the largest ball in his fingers and threw it in order to make it 'break' on touching /

touching the floor, so that the actual movement of the ball was in a different direction to the direction of throw. The response then required of the child for a vision rating was one of going straight to the ball; searching around for it was regarded as an error of vision. The $1\frac{1}{2}$ " ball thrown to a distance of six to seven yards, was said to correspond roughly to an acuity of 6/60, and the $\frac{3}{4}$ " ball to an acuity of 6/24. The obvious criticism to this test lies in the child's possible lack of attention and in his reluctance to follow the ball to retrieve it. Also it is more likely that the child would naturally follow the direction of throw if he has not attended to the progress of the ball's flight and its 'breaking'. It would seem likely that searching would be the type of response that this test would elicit (perhaps because of the young child's restricted visual field - see p.194).

HEIMANN in 1905, recognising the difficulties imposed on the young child by a verbal response to pictures such as Wolffberg's, used the principle of the E test or the Landolt C in the construction of his chart. He had two aims in view which he stated as ...

"to make the act of thought, which is closely connected with the act of seeing in every testing of the faculty of vision, as simple and easy as possible; and secondly, to enable the physician to test the sight in such a manner that the child, who is naturally bashful and reserved on such an occasion, need not speak."

10.



6.



5.



Fig. 45: Heilmann's Hand chart (1905).

Heimann claims that the act of thought required of the child in his test, is adapted to the lowest degree of intelligence, and that the child's performance is improved by stimulating his imitative instinct. Since the child had often been required to use his hand in response to the other directional tests, Heimann chose a picture of a hand as the stimulus, so that the relationship between the stimulus and response was clearer to the child (Fig. 45). The child was shown the largest hand at a distance of about 19", and the picture was moved to and fro while the child was encouraged to imitate the directions being represented, with his own hand. Heimann also recommended that the pictures be presented singly to prevent confusion on the part of the child.

In 1909, a picture test was designed by McCALLIE solely with kindergarten children in mind. (This test, it would appear, is still published in Chicago which speaks well for its prolonged success in clinical practice.) The optometric principle of positive and negative elements was dispensed with in this test, although the Snellen size convention was still adhered to. This test, in fact, made use of the minimum visible aspect of form perception in a fashion somewhat similar to Wolffberg's pictures. It cannot be simply classified /

classified as a minimum visible test however, for the visual acuity target was incorporated in a larger form, and a certain amount of meaningful search within the picture would have to have been carried out before the acuity target could be located. The test was constructed as follows:- a series of cards, depicting a boy, a girl, and a bear, each with a tennis racket, was shown in succession to the child. One of these figures had the ball, a dot, and the child was required to say which of them had the ball. The test was made by the approach method. Presumably the child would first be given practice in naming the three figures. RYCHENER (1958) reported that this was an excellent test in practice. As has been mentioned earlier, there appears to be an objection to the use of a constant pattern for visual acuity measurement in the young child ... the child's ability over a range of patterns with different forms and orientations should be made (Sheridan 1960). But although the target in the McCallie test is a recurring dot, it has been pointed out that this requires to be located within a particular figure, and a correct response requires a further discrimination between three similar figures (although this is not critical as regards size).

Löhlein (1910) in his investigations found that Wolffberg's figures were recognisable at twice their calculated /

calculated distance. He then took a number of assorted pictures and presented them to a group of emmetropes from a great distance. This distance was gradually lessened, and he found that some of the test objects were distinct from others in that they were recognised correctly by the majority of subjects at approximately the same distance. Löhlein then gave the name 'Erkennungskonstanz' or 'Constancy of Recognition' to this phenomenon, and the test objects selected on this basis were said to have good constancy of recognition and thus were valid items for an acuity chart. Thus the optometric principle was discarded in favour of an empirical evaluation of the recognisability of each test item. Löhlein then selected pictures from those which had passed the criterion and tried them out with groups of emmetropic children of various ages. The result was a pictorial chart without, as Østerberg (1936) said, "optometric pretensions". This empirical approach certainly would appear to be more promising, especially since Snellen's findings on part-separation by adult subjects do not necessarily have any bearing on the perception of whole configurations, and especially by child subjects. But Østerberg, in attempting to evaluate Löhlein's findings failed to gain constant results, some pictures being recognised more easily (ladder, cross) than others (posthorn /

posthorn, scales, candle etc.). Also, sex differences in constancy of recognition were found, and this attribute of constancy had already changed four years after it was established, when Østerberg's study took place. Østerberg concluded from these observations that Lohlein's 'Konstanz' would not keep constant for any length of time. His efforts, nonetheless, represent progress towards an appreciation of the psychological elements in the perception of a total form, and a realisation of the value of the empirical method in such studies.

EVANS' work began with a criticism of existing picture charts then in common use (1919). He referred to those of Reber, Seitz, Ettles, Wolffberg, Thorington, but unfortunately references to these works were not given. The most pronounced faults, he stated, were in the selection of items. These were made in silhouette, line, shading, and combinations of these, and employed a multiplicity of characters whose names might easily be confused, which were markedly inaccurate as a measure of visual acuity, and which represented objects unfamiliar to the young child. Illiterates, he stated, may be either mentally deficient or of normal adult mind, and the chart if constructed to reach the young child, can be followed by them, but not the reverse. In the construction of his test, he observed the following principles:- /

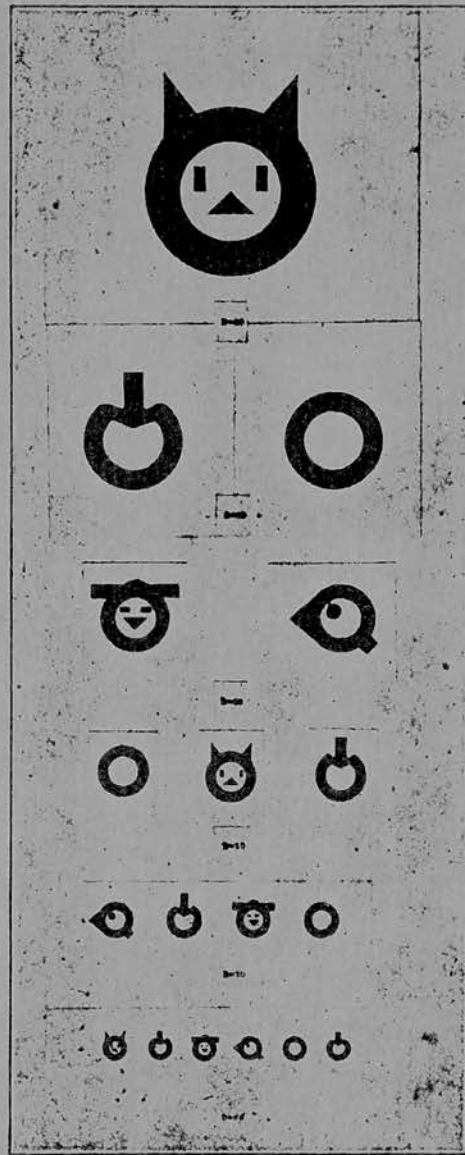


Fig. 46: Evans' chart for children (1919).

principles:-

The characters must conform closely to the international standard (optometric).

A circle is used to form the body structure as a basis for the objects.

1' projections from the basic circle measure the capacity to perceive and recognise the individual characters.

Few characters are used so as not to overtax the child's vocabulary or his powers of concentration.

The items must be familiar to a child of three or four years old.

Evans studied drawings made by young children, and noted those objects which most attracted the child and which he most successfully reproduced. Those which were out of proportion or formed black masses when subjected to the optometric convention were discarded, and those items finally used were the circle, the cat's head, the man's head, the apple, and the bird's head. Evans claimed that the chart has given good results with children as young as three years. On first inspection, the chart (see Fig.46) bears a resemblance to Wolffberg's figures, but unlike his items, the pictures in this test were arrived at from some empirical evidence about the perception /

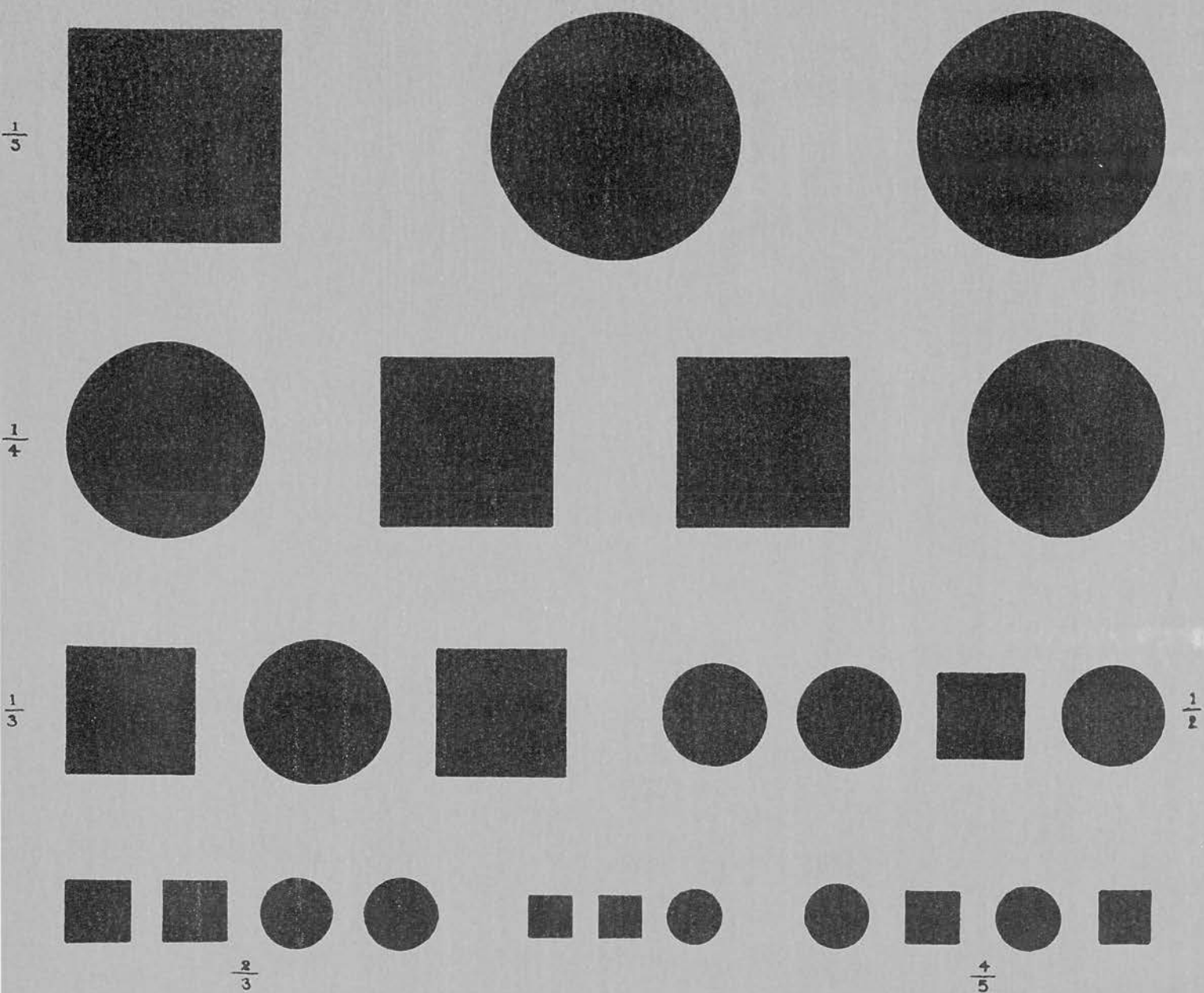


Fig. 47: Dor's chart for use with illiterates (1920).

perception of young children. Nonetheless, it would appear that perception of the given object might not depend solely on the 1' projections as the principle of construction seemed to imply.

DOR (1920) conceived of his chart during the war for use with illiterate soldiers. It consisted of solid circles and squares of the same area (See Fig. 47). He restricted his choice of items because he wished visual sensitivity to be measured at all positions on the test chart by comparable stimuli. This principle, he claimed, was more physiological than that normally adopted in letter charts, and was previously realised in the construction of the Landolt C and the Pflüger optotype. Dor's chart differed from theirs, however, by using the whole symbol as the basis for the optometric calculation. A visual acuity of 1, i.e. $5/5$ ($6/6$)^{*} would distinguish the circle from the square at five metres. At this distance, if the circle was superimposed on the square, the four corners of the square would overlap the circumference of the circle by 1mm., at each corner; for a visual acuity of $5/10$ ($6/12$)^{*}, this overlap would be 2mm., and for a value of $5/50$ ($6/60$)^{*}, the overlap would be 10mm., etc. Since this test was designed for illiterates, they were merely to indicate by /

* Note: Conversion from original notation.

by a gesture whether they saw a square or a circle. Dor concluded from the simplicity of the test that it would also be most practical for use with children, but we have already seen that such an assumption is quite unjustified.

PECKHAM's work in 1932, began with a reiteration of the psychological nature of a measure of visual discrimination. He then proceeded to point out the error in the optometric assumption of 1' as the criterion of normal vision (an assumption, he claimed, "made upon irrelevant data, and upon far too few cases".) Nevertheless, he acknowledged the usefulness in practice of the Snellen principle. He proceeded to design a test for the estimation of visual discrimination in children modifying a technique invented by George W. Bailey, an optometrist of New York. The Snellen units were incorporated into a design of geometric figures and simple pictures of common objects which were then placed at 10' from the subjects. Because of the difficulties encountered in a child's verbal response, the latter was discarded in favour of a matching procedure which dispensed with the need for language. Enlargements of the items were made of a black fibrous material $\frac{1}{4}$ " thick. These cut-out figures were placed on a white tray about 9" x 11" which contained narrow shelves for holding /

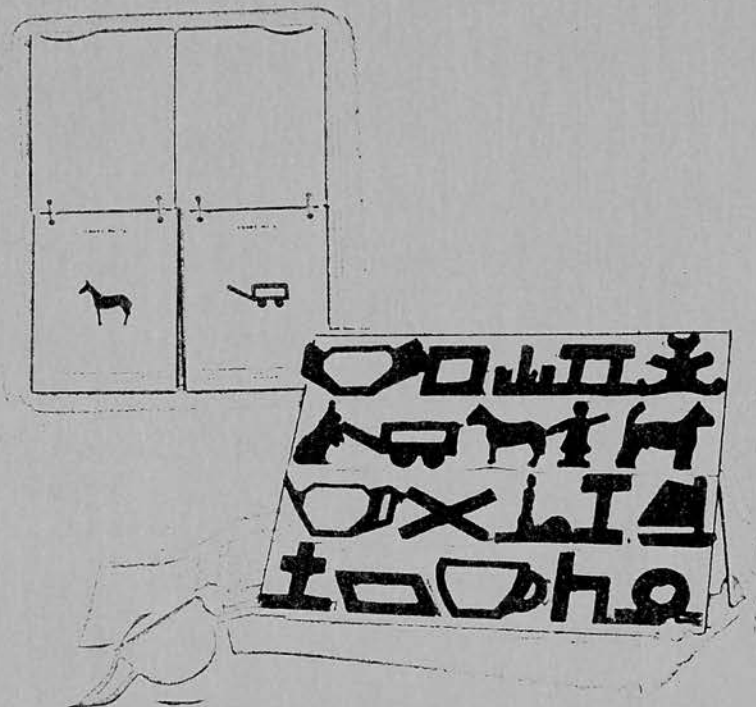


Fig. 48: Cut-out figures for matching against Peckham's test figures (1932).

holding the figures, and which was inclined at about 80% from the horizontal (see Fig.48). This tray was placed in front of the child who was required to match the test cards against the cut-outs. The test itself was designed for presentation at 10' for it was found that the test at 20' confused children. The child was required to "choose the figure just like the one over there". With younger children this procedure required further demonstration. Peckham reported from practice that this test was a reliable one, and also that the assumption that young children do not have good vision is an erroneous one. Again, however, co-operation was essential, although the test appeared to provide sufficient motivation for the young subjects. This appears to be the first time that matching was used as a response in the acuity testing of children, and with obvious success. It should again be noted that Peckham found in children visual acuity values similar to those of adults. His claim, however, that the pictures were constructed on the basis of the 1' angle elements is unjustified. Inspection of the test objects shows great variation in shape, with differences in the proportion of over-all black areas to white. Since some of the objects are quite dissimilar in this respect, correct matching could occur without clear perception of /

of the object i.e. by elimination of the other shapes. For example, only the boat has that particular mass of black area. Thus, appreciation of the general configuration of this object without discrimination of details, could lead to a correct match. On the other hand, confusion resulting from the great similarity of the bowl, the teapot, and the cup, might possibly induce the child to make an incorrect match when in fact his perception of the object has been accurate.

Østerberg (1936) has already been mentioned in connection with his evaluation of Lohlein's 'Erkennungskonstanz'. Although as a result of Østerberg's findings, the 'constancy' of Lohlein's results was in doubt, Østerberg was aware of the contribution that this method could make to a knowledge of vision testing in young children. But as he also found himself in sympathy with Wolffberg's approach, he felt that the optometric principle was an indispensable part of test construction. The result was a sight-test chart ...

"of pictures which have been both constructed to the greatest possible extent on optometric principles and at the same time regulated by psychologic-practical experiments."

The problem lay in the constraints that the Snellen principle imposed on the representation of objects and the scope of children's concepts placed on their choice. Thirty-eight /

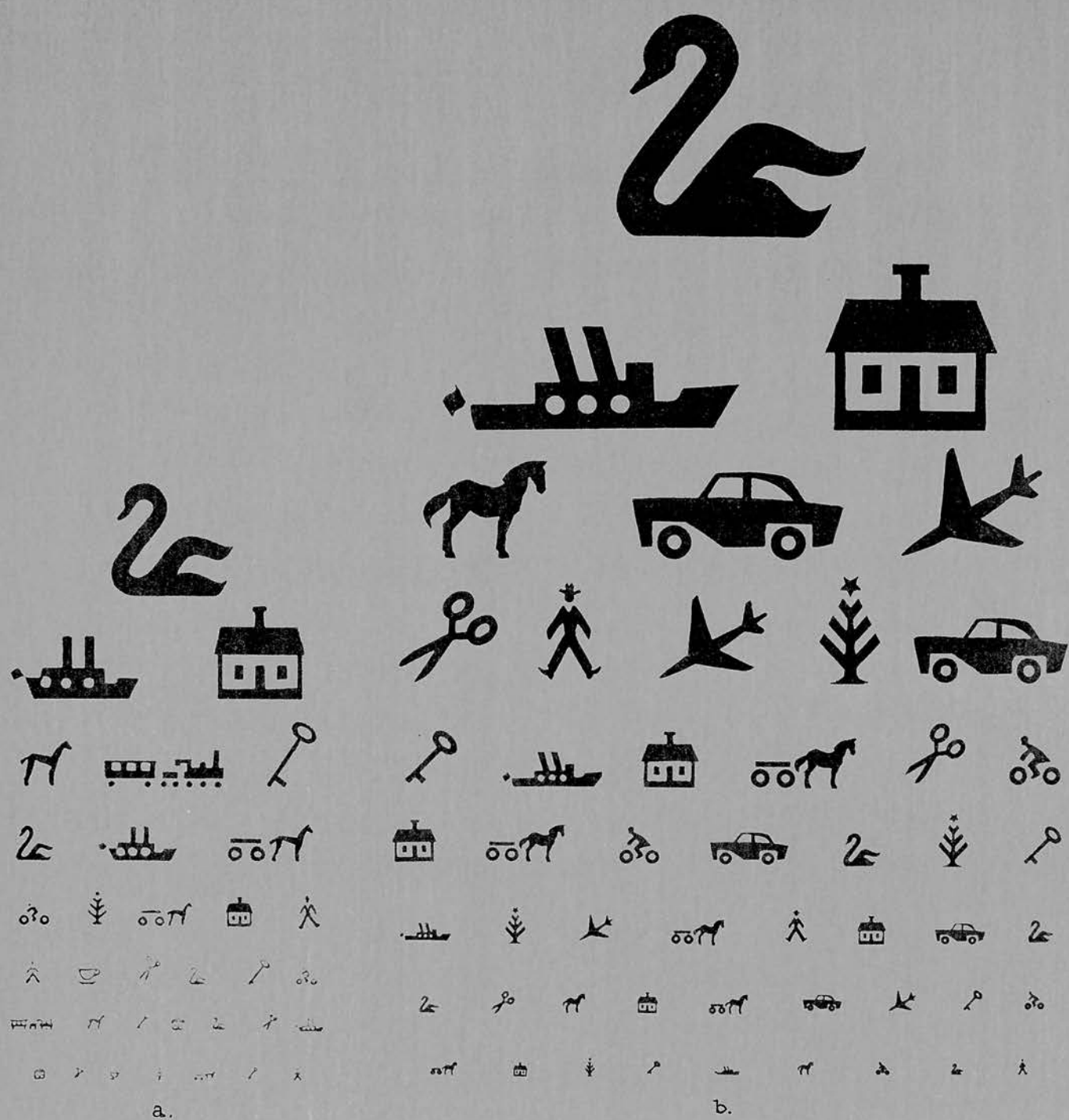


Fig. 49: Österberg's Pictorial Chart for children - 1st. edition, 1936 (a), 5th. edition, 1965 (b).

Thirty-eight large drawings were made, composed wholly of positive and negative elements of the same width (1cm.). These pictures were shown to a number of children between two and five years, and some were rejected as a result on this trial of consistent failure to be recognised. Østerberg also observed that broad basic delineation of the figures without decorative details was an aid to the child's perception. The twenty-six figures which remained after the first rejection, were next shown to ten adult emmetropes at a distance of forty metres, and they moved forward towards them until correct recognition took place. The distance of correct perception was noted for each picture, and found to vary with different pictures. Those with low recognition value were rejected, and the eighteen which remained were similarly tested with thirteen emmetropic children. At the same time, however, a few slight alterations were made e.g. the roof of the house was made thicker etc. These alterations resulted in a more uniform distance of recognition, although some of the pictures were now found to be optometrically incorrect. The chart was tested further with twenty-six children and the least stable figures were excluded, leaving twelve pictures of which the chart was finally composed (Fig.49a). Østerberg reported /

reported from clinical usage that the test was satisfactory and was comparable with Snellen letters. He thus aimed at **reconciling** the optometric principle (Snellen) with the principle of constancy of recognition (Löhlein). To adhere rigidly to the first principle at the expense of realistic representation had proved, as in Wolffberg's chart, to be the wrong approach. It seems surprising, though, that Østerberg concerned himself with trying to incorporate this optometric principle into his constancy experiments, especially since he later made certain modifications which contravened the Snellen convention. The final chart, in fact, appears so far removed from optometric principles with as wide variations in areas of black and white as were seen in Peckham's test. The use of naming is also not a particularly reliable method with the pre-school child, and it appears that the result of Østerberg's work shows little advance on the work of Lohlein, except that he recognised the changing nature of 'constancy' and took this into account in a later edition of the test (1965, 5th edition - see Fig. 49b). It is significant however, in its emphasis on the empirical approach to a problem of this kind. In a study by SAVITZ et al., (1964), the Østerberg chart was administered to ninety-three children together with the ALLEN picture test (1957) /



Fig. 50: Coloured picture chart for Kindergarten children - Berens (1938).

(1957) and the American Optical Kindergarten Chart (1946). Almost all of the children preferred the Østerberg chart and many of the figures were correctly named in spite of an expectation that they would prove unfamiliar to the children e.g. skeleton key, and scissors. The success of this test is thereby demonstrated in spite of objections to certain aspects of it.

BERENS (1938) was the first to introduce a coloured picture chart for testing the acuity of kindergarten children. He realised that in order to improve performance, interest had to be stimulated, and his purpose was to do this by presenting figures with which the average child of over three years was familiar. The chart was coloured to elicit interest, and Berens claimed that the figures had been drawn to conform as nearly as possible with 1' and 5' angles. His items differed so widely from one another (see Fig.50), however, that it would seem that correct recognition could have been made without a discrimination of parts, and the pictures certainly did not conform to the Snellen principle. If one inspects the lowest line of Fig.50, it can be seen that the over-all configuration is sufficient to differentiate between the items when a perception of parts is no longer possible. Also to introduce colour into /



Fig. 51: The Sjögren Hand test (1939).



Fig. 52: American Optical Co. Chart (1946).

into acuity testing is to introduce another dimension which might be difficult to control, and contrast between figure and background might be noticeably affected. Visual acuity charts were initially designed devoid of colour, in order to separate colour vision from the aspect of the perception of form per se which required to be assessed for purposes of correction. There is no reason other than this why coloured objects should not be used, but this use would require to be carefully controlled and selected so that perception of the form of the item would not be impaired for those whose colour discrimination was weak.

SJÖGREN (1939) produced another hand test very similar to that of Heimann. Since the hand is probably the first part of himself the child is aware of, a picture of a hand was used with fingers extended and pointing to any one of the four cardinal positions. The child was then required to imitate the position of the pictured hand with his own hand. The figure on the cards was that of a

"somewhat conventionalised hand where the fingers and the intervening spaces are calculated on the Snellen principle in such wise that when regarded at the distance indicated on the back of every card, they appear under an angle of vision of 1'" (Sjögren 1939) - see Fig.51.

When very small children were to be tested by this method, Sjögren /

Sjogren recommended that the procedure be demonstrated close up and with a large figure. He claimed that experience had proved that children down to the age of two years could easily manage the test. In their study of 1964, Savitz et al., tested seventy-two children aged two and a half to four and a half years with this test. Most of the children enjoyed looking at the hand card, calling it 'hand', 'glove', 'mitten', or 'elephant'. However, the ability to match directions was limited particularly for horizontal positions. Of the seventy-two tested, only forty-two of the children could perform the test, and the relationship between testability and chronological age was more pronounced for this test than for the other tests studied. The use of positional representation has been widely criticised (see SHERIDAN 1960) because of the common occurrence of 'mirror-writing' at this stage. On account of this, only the up-down positions can reliably be used, leaving a 50% chance of correct guessing. Sjögren's method comes under this criticism. (See also FFOOKS 1965 p.98-99 for reason for difficulty of horizontal positions.) There is, however, a much more serious objection to the use of this test. It also applies to the Heimann hand test. From inspection of Fig.51 (and also Fig.45), it will be seen that the dimensions of the hand are such that /

that the distance of the point of maximum height from the base, is much greater than the distance between the points of maximum breadth. Thus, it would be possible to determine in what axis (horizontal or vertical) the hand was pointing by a perception of the over-all dimension. The spacing between the fingers and their 1' subtense appears to be irrelevant in such a judgement. This is even more apparent in the Heimann version. Again, the use of the Snellen principle seems quite superfluous in these tests. Certainly they conform to the over-all 5' angle, but it will be remembered that according to Snellen the important thing in the reading of a letter of this dimension was not its total subtense but the separation of its parts. If the stimulus can be resolved without the perceptual separation of elements, as is probably the case in these hand tests, then the idea of the Snellen convention is not being utilised in such tests.

EVANS (1946) appears to be the first investigator who used the attention response as a determinant of visual acuity. Black iron filings of graded size were moved about on a white opaque tray by means of a magnet manipulated underneath the tray by the examiner. The smallest array of filings which attracted the child's attention was taken as the index of acuity. Evans believed /

believed that children as young as three months could give reliable responses to this test, but its use with older children is questionable, for different laws of attention will operate at an older age. And if the child failed to attend it might be an unjustified assumption that he was unable to see the filings. It might also be possible that the sound of the magnet moving beneath the tray would be sufficient stimulus for attention, even if discrimination was not taking place.

Also in 1946, the AMERICAN OPTICAL KINDERGARTEN CHART appeared (Fig.52). This chart consisted of both solid figures and outline drawings whose general shape could easily be differentiated one from another because of great dissimilarity. Also, it can be seen from the lower lines that the shapes of the solid figures tend to become blurred with a reduction in size. This type of stimulus has been criticised as presenting a meaningless mass of black to small children. Savitz et al., (1964) also studied this chart in their group of pre-school children, where they found that generally it was unappealing. Few children knew four of the figures, and 'hand', 'coffee' (for cup), and 'valentine' (for heart) were the most frequent responses. Few children recognised the sailboat, and the other figures were named only /

only when a concrete figure was made of them, e.g. 'wheel' for circle, 'window' for cross, and 'sky' for moon or star or flag (with the star on it). It is probable that in 1946 when the chart was designed, these figures represented meaningful and interesting stimuli for children. The apparent change of emphasis in interest over periods of time, therefore, should be taken into account when picture charts are designed. It would seem that they require frequent revision in order to retain their validity as tests of vision.

ALLEN (1957) recognised the usefulness of picture charts in an approach to the problem of vision testing in the three year old child. He also commented on the lack of objective standards for pre-school children. His test was designed after the following considerations:-

- (i) pictures have greater reality and interest for the child;
- (ii) the sense of form is most easily utilised in an otherwise empty field (EHLERS 1952);
- (iii) since the importance of visual angles is paramount, careful attention must be paid to the proportion of black to white in the internal structure of a design i.e. drawings should not be distinguishable from other pictures in the series solely on the basis of outline;
- (iv) the distance at which a given picture can be recognised by a /



Fig. 53: Allen's Preschool visual acuity test (1957).

a normal child of a certain age must be established empirically. In this contribution, therefore, we have a re-iteration of Østerberg's work, with the exception that Allen's drawings were designed for single presentation and that they were more truly representative of the Snellen principle, although here again there was no great uniformity about the distribution of black and white elements. With these considerations in mind, therefore, Allen designed a series of black and white pictures which could be recognised with about the same facility as the letters on the twenty-five and thirty feet lines of the Snellen chart. Drawings were viewed through blurring lenses in an attempt to produce pictures which would be recognisable at twenty feet, with acuity levels no lower than $20/25$ ($6/8_{app.}$)^{*}, or $30/30$ ($6/9$)^{*}. Trials with a group of pre-school children resulted in a final selection of eight pictures. These seemed to have the highest interest value and the most consistent levels of recognition for the group. Allen believed that the method of individual presentation of items and his method of construction represented improvements over picture charts then in current use. Great care was taken in the drawings to avoid intersections of lines because of the possible effect of blurring (see Fig.53). The /

* Note: Conversion from original notation.

The test was to be administered as follows:- The eight pictures were rapidly shown to the child at close range for identification. Any picture evoking a negative response was excluded and the child's special names for any of the pictures was noted. One eye was then occluded and the pictures were presented at twenty feet and withdrawn as soon as the child answered or looked away. If no results were obtained with either eye at twenty feet, the distance was shortened to fifteen feet, or the examiner could walk towards the child until identification of the picture took place. Allen found that most normal four year olds could recognise all the pictures at twenty feet, and three year olds could normally recognise them at fifteen feet. Correlation between this test and the thirty feet illiterate E test showed that the maximum distances of recognition were about the same for each. Vision of 20/30 (Snellen) (6/9)* gave results under twenty feet for every picture except one. Vision of 15/30 (6/12)* did not permit recognition of any of the pictures at twenty feet. Vision of 10/30 (6/18)* gave maximum recognition distances in the vicinity of ten feet. Allen concluded by recommending the E test as the most useful for children who can understand it, but pointed out the usefulness of /

* Note: Conversion from original notation.

of the picture test for those children who were unable to perform the E test. In their study of various tests of vision, however, Savitz et al., (1964) found that the Allen test lacked popularity with their group of ninety-three children (aged $2\frac{1}{2}$ - $4\frac{1}{2}$ years). The pictures were called unusual names e.g. the Christmas tree was called 'lamp' and 'lady's hat', and the birthday cake was often called 'fire' or 'fire on plates'. The single presentation of each item is, however, undoubtedly an aid to child-testing.

Berens (1958) stated that although it was exceedingly important to determine the visual acuity of young children under four years, to obtain even an approximation of acuity was often practically impossible. He found the following test useful for this purpose. An open box, neutral gray in colour, containing twenty red, green, blue, and white enamelled spheres of various sizes (15, 10, 5, and 3mm. diameter), was placed before the child at a distance of 25cm. The approximate visual subtenses were : $3^{\circ}14'$; $2^{\circ}6'$; $1^{\circ}5'$, and $0^{\circ}39'$ respectively. The reflection factors of the spheres were: white 87.7%; green 38.8%; red 34.5%; and blue 6.5 - 7%. One or more of the spheres was left in the box which was brought to within 25cm. of the child's eyes. The box was moved, activating the ball to attract the child, who was /

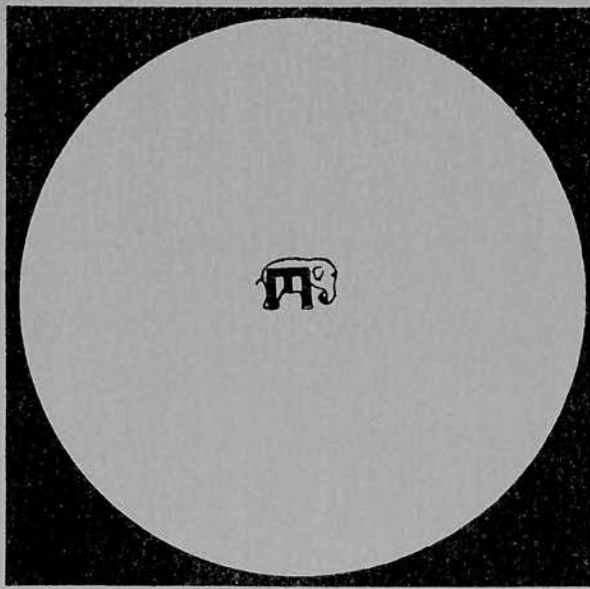


Fig. 54: Circular chart used in acuity testing (Fink 1959).



Fig. 55: The Ziobrowski Optotype key card.

was thereby stimulated to reach for the object and remove it. Depending largely as it does on attention, this test may not be too reliable.

RYCHENER (1958) recommended that the illiterate E test be used, being the most satisfactory test for practical purposes. The parents were first given a large cardboard black E which they took home. An explanation was given to the child that this represented a table with three legs which point down, up, right or left according to the way the table is turned. The child was then trained to point his finger in the direction of the pointing legs. After proficiency was achieved using both eyes, one eye was occluded and the test carried out at the prescribed distance in the consultant's office. This appears to be an ingenious way of presenting the E test, but it has still all the disadvantages of this test. It might, however, be more appealing to the child, and thus more reliable.

Another variation of the E test was described by FINK (1959). Here, the E was superimposed on the body of an elephant on a circular chart (see Fig.54). The chart could be rotated to produce different orientations of the E. Again it was recommended that prior practice should take place at home. As the E was of fixed size, this test used distance as the variable. This, however, would /

would have the drawback of possible fluctuations in illumination level as the examiner or the child moved from one part of the room to another.

After many experiments with various test forms, ZIOBROWSKI (1959 - cited by DOLEŽALOVÁ 1964) chose six silhouetted images (circle, house, duck, horse, cat and aeroplane - see Fig.55) as being the most distinguishable one from another even when greatly diminished. The empirical approach was then used to fix their sizes for various distances using a large number of emmetropic children and adults. Thus, for example, for the same distance, the circle was smaller than the house, so that they were equally distinguishable. This test was used with a great deal of success with otherwise untestable children in the Eye Department of the Marienbad hospital, where for greater success, the pictures of the optotype were copied onto separate cards. The child was required to name the objects or otherwise point out the appropriate one on a key card which comprised the six symbols. Doležalová (1964) reported that these pictures pleased the children and made for willing co-operation. In this way, she and her colleagues were able to examine the vision of 70% of two to three year olds even at a first examination. They also found in practice that a distance of three metres made for a more ready response from the children /

children than a distance of five or six metres. It is interesting to note the existence in this test of two different sizes of object appearing on the same line of the chart. If the house at a distance of five metres subtends five minutes of arc, then the circle can subtend no more than three minutes. Yet, if the chart was constructed on strict optometric principles, then the test items appearing on the same line would require to subtend the same visual angle. This empirical approach has thus indicated that the 'minimum cognoscible' varies with different test objects, and that this variable must be accounted for in the construction of a test. Previous optotypes which utilised the empirical approach were composed of pictures which had similar 'cognoscible' values. In this test, differences in 'cognoscibility' is accounted for by changes in size of the differing symbols. The necessity of the empirical approach is again clearly demonstrated.

Sheridan's work (1960 a and b) was the outcome of dissatisfaction with existing children's vision tests, in particular picture charts and the illiterate E. Pictures presented children with the problem of relating representation to solid object, and the E test, while simpler and yielding better results, relied upon the sense of directionality which is often confused in young children; also, since a constant pattern was being presented /

V

T

O

H

X

Fig. 56: The 5-letter key card for Sheridan's Stycar Vision Test (1960).

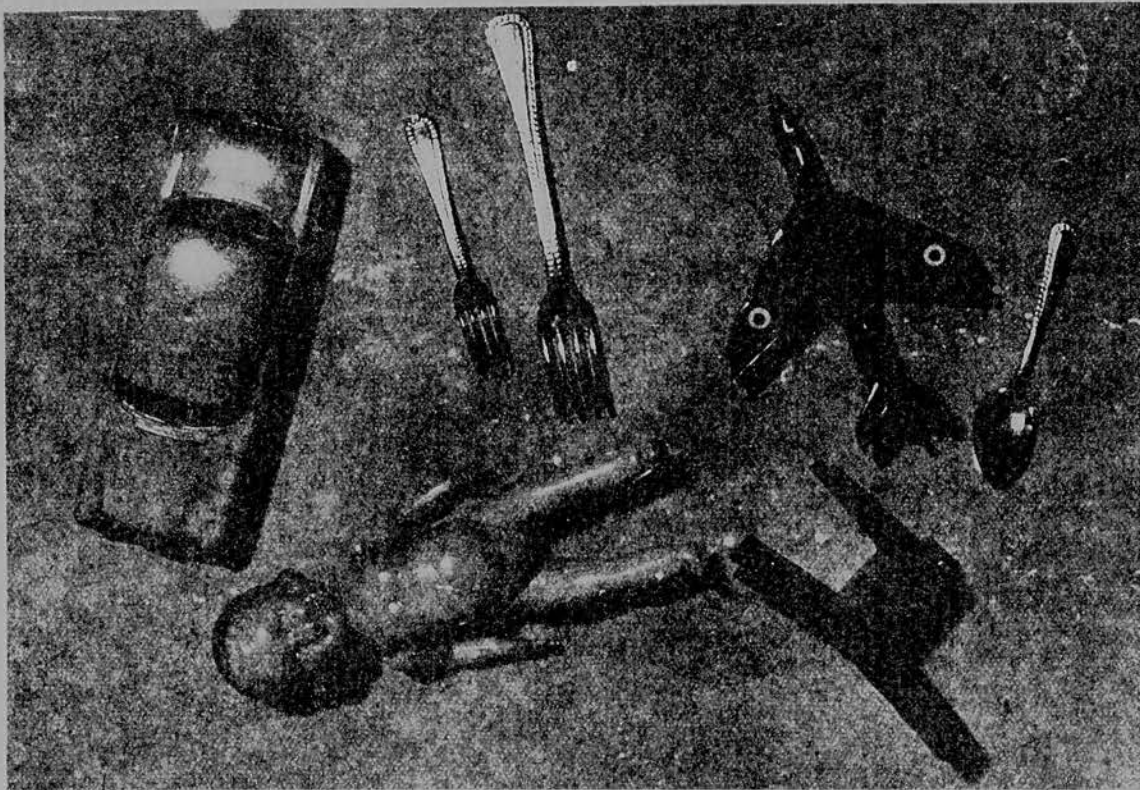


Fig. 57: Sheridan's Miniature Toy test (1960).

presented, the child's ability to discriminate different configurations was not being tested (PUGMIRE and SHERIDAN 1930). These authors then proceeded to search for suitable material with respect to findings on the psychological development of the child and with an acknowledgment of the necessity of standard procedure in any test situation. As a result of these investigations, three sets of material were considered to have potential in the testing of the pre-school child - single letter cards, shaped wooden blocks, and miniature toys. The first and last have been extensively tested, but the wooden blocks are still under investigation (Sheridan 1960 a and b). Nine letters based on the optometric principle were originally used for the single cards, and these were chosen on the basis of shapes which older children (five to seven years) could copy. Now it was found that although younger children were unable to copy the letters, they could match them against a corresponding set. Five letters were then selected (H T V X O) for use with three year olds (seven for four year olds) and designed for use at ten feet (where rapport was found to be greater). The letters were presented singly and the child had a card containing all five letters from which he had to select the appropriate one (see Fig.56). The procedure was outlined as follows:-

"C (child) is given the appropriate key card. E (examiner) first establishes rapport with him at a conversational distance, showing him a selection of the letter-cards and saying as he shows each one ... "I've got one like this and you've got one - Show me yours ... Good!" If necessary e.g. with a deaf child or the mentally handicapped, E should take C's index finger and put it down on the correct letter. When E is satisfied that C understands the procedure, C's left eye is occluded and the test is carried out at ten feet. The cards must be presented at the child's eye level in a good light. A little preliminary practice with similar letters at home or in the nursery will greatly improve performance." (Sheridan 1960a).

Standards were given as follows:- four years: all normally intelligent children can match all seven letters (A U X H T V O); three years: 80% can match five letters (A and U are excluded); two years: 30% can match four or five letters. Sheridan concluded that the child with normal vision might be expected to match all the letters down to and including the smallest at ten feet with each eye separately i.e. vision corresponding to 6/8 left and right eyes. These norms, however, are only likely to be achieved in the hands of experienced examiners. The miniature toy test (see Fig.57) had a similar standardisation and was found to be particularly useful with severely handicapped children, especially those with low intelligence. It was not possible, however, to establish the precise relationship between this test and /

and the Snellen letter test.

It is unfortunate that Dr. Sheridan in her strict adherence to psychological findings overlooked the empirical nature of the 1' visual angle of minimum resolution, and accepted the traditional view that children of this age can be expected to achieve only 6/8 or 6/9 vision. There is an increasing number of findings to the contrary. Sheridan also reported that some of the younger children showed a tendency to confuse V and X. McDERMOTT (1965) found that in addition, there was a strong tendency to confuse T with H. There is certainly an obvious similarity in the components of these pairs. Is there then a general tendency among young children to confuse like forms? In the present study (see p.52) of 200 pre-school children (aged 2.11 - 5.6) it was found that the tendency to confuse similar forms (e.g. square and quadrilateral, circle and ellipse) in a matching task was much greater in the younger than in the older age groups (although some confusion still existed at the five year old level). The indication is that similar forms in a choice-situation will reflect the development of the child's matching ability which tends to become more differentiated with age. Dissimilarity within similarity can be handled more successfully the older the child (whether this is a manifestation of improving discrimination /

discrimination, or improving methods of scanning, or a refining of understanding of verbal instructions). Thus acuity tests for three year olds which utilise pairs of similar forms for matching will probably cause confusion in the child. Indeed an error resulting from such confusion should be expected in such a situation, and thus the child's discrimination (in the strictest optical sense) is not necessarily being tested. The cognitive component of the Sheridan Stycar letter test is apparent when one compares it with the item Form Discrimination (Year IV) in the Stanford-Binet Intelligence Scale (Form L-M).

In the study mentioned previously by Savitz et al., (1964) the Stycar test was also assessed. It was reported that the children did not find the letter test attractive, even those who could competently match the letters. Of the fifty-nine children tested, only twenty-six were testable by this method. Many of the thirty-three non-testable children were able to match the O and a few more could distinguish the X and V but often confused these two letters. It was also noted that the test became more interesting and elicited more accurate responses when the child was allowed to use pennies to cover the appropriate letters on the key card. The similar version of the near-vision test was more successful /

successful. It would appear from this observation that the tendency to confuse like forms will be increased with distance when the stimulus will be less distinct and so more likely to accentuate a tendency already present. The miniature toy test appears to have had greater success, particularly with younger and less intelligent children, but its form makes it difficult to compare with other acuity values, and it does not appear to detect the presence of slight defects (although discrimination between the smaller knife, fork and spoon is believed to approximate to 6/6 vision (Sheridan 1960)).

CARLEVARO and OUIILLON (1960), like Sheridan, were opposed to the optometric principle being applied to picture charts, as this seemed to lead to confusion and inaccuracy. Optotypes, nonetheless were necessary, and a test had to be found which suited the psychology of the three year old child. A child of this age, they said, did not possess such a developed sense of difference as did the adult. Examples of generalised concepts were given in support of this statement e.g., at this age, a St. Andrew's cross and an ordinary cross are one and the same cross. These authors then went on to develop the 'Opto-Psycho-Pedagogical' Method. A long study preceded this in which different signs were studied with a group of /

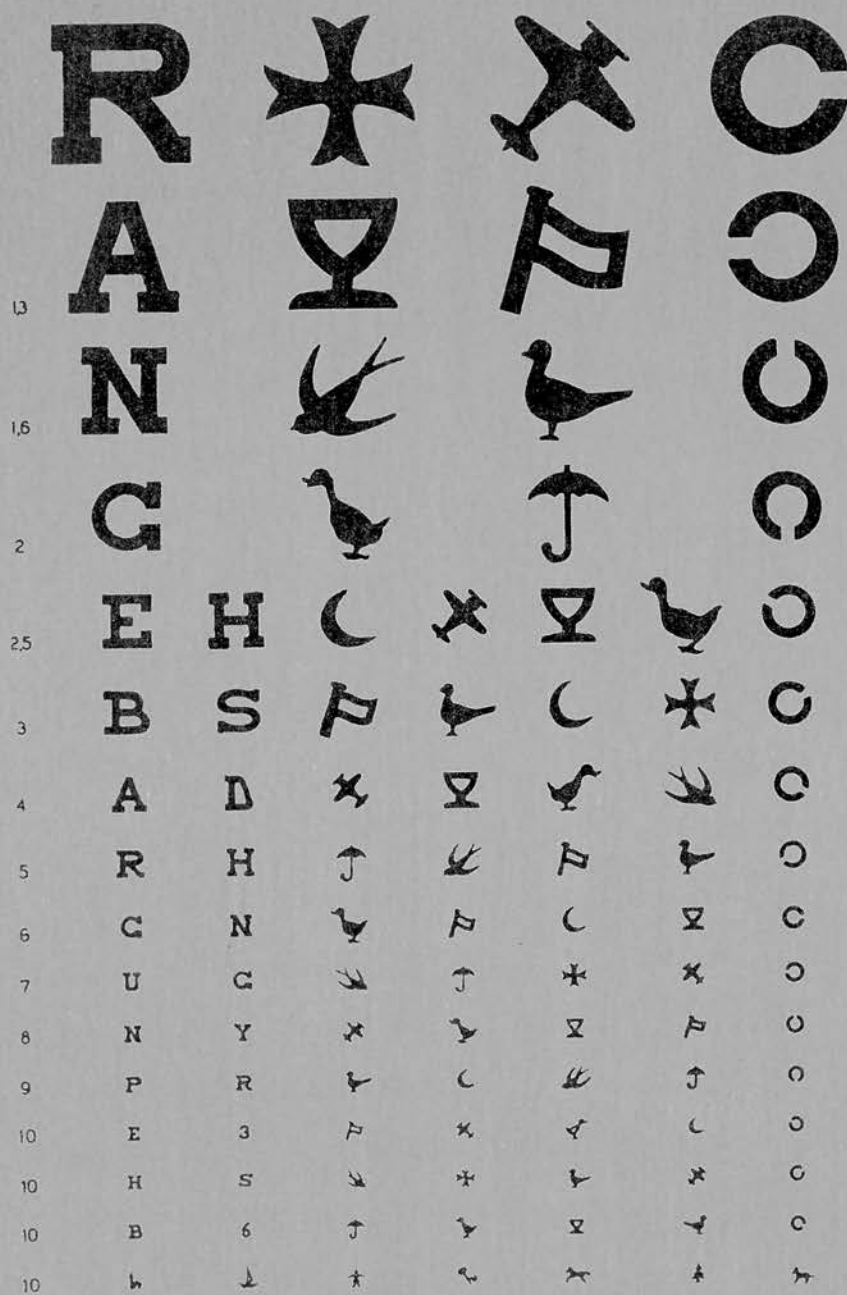


Fig. 58: Traditional charts used in the development of the Carlevaro Optotype.

of nursery children. The signs were abstracted from traditional charts for children and illiterates (see Fig.58). Finally twelve shapes were selected empirically which were well differentiated and which retained their structural characteristics even in the smallest presentations (see Fig.59). The experimentation from which the signs were derived, was carried out with reference to psychological laws of perception. The authors gave an example of this. Although it is necessary to consider the visual angles under which the object is viewed, it is also essential not to forget that perception depends on other factors as well e.g. the total configuration and not simply the component elements in an object is important in perception. The twelve signs chosen resembled a series of letters reduced to their essential characteristics, but these could not be confused because of their high degree of differentiation. They were also equally easily identifiable and did not change their characteristics when they were reduced in size. In addition, these shapes had the advantage over letters in that they could not be 'interpreted' (or inferred) because the perception of one part of the signs is not sufficient to suggest the total representation. The selection of twelve optotypes reduced the risk of chance-guessing. The chief advantage of /



Fig. 59: Key card to the Carlevaro Optotype.

of this method, according to the authors, was that it allowed the same optometric principle to be used for children as is used for adults, and thus permitted the comparison of acuities at different age levels (a comparison which can be made only if the acuity values have been obtained by means of comparable optotypes). The authors also used a response based on the game of 'lotto' where the child was required to cover the appropriate sign on his key card with a counter. This made the test procedure more of a game situation which the children responded to favourably. The key card (Fig.59) will be seen to resemble closely the optotypes of Sheridan. It would seem from a first inspection that, contrary to what the authors believed, these signs might not prove sufficiently different to prevent confusion in the young child. For example, the Z and the arrow use similar diagonals and horizontals. Therefore the same objections as those to Sheridan's work, might also apply here. It should be noted, however, that the child's full involvement in the response as in this instance, should make for reliable results.

KAIIVONEN's work (1963) was directed towards a screening programme in Finland for the detection of amblyopia rather than a devising of an exact visual acuity test. Four pictures (resembling those of Peckham /

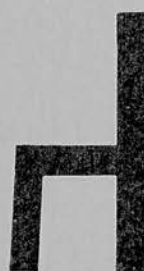
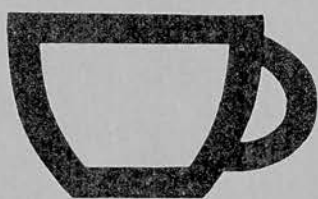
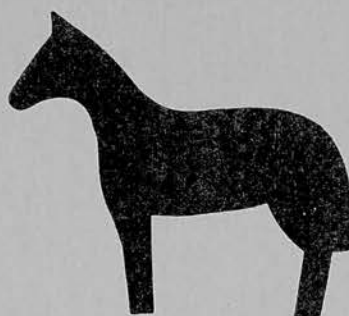


Fig. 60: Cards used in Kaivonen's screening programme (1963).

Peckham 1932, and also appearing on the Bausch and Lomb children's slide), horse, child, cup and chair (Fig.60), were each printed on postcard-sized pieces of paperboard. As visual acuity of 0.3 (6/18) can be regarded as the limit of an apparent amblyopia, the size of the pictures was equivalent to the 0.5 (6/12) optotype when viewed at a distance of five metres. Children who failed to see the test pictures with one or both eyes at this distance were referred for follow-up investigation and treatment. A total of 1,327 children aged four to four and a half years were examined in fifty-five public health nurse districts in Finland. The results up to the time of the preliminary report appeared to indicate that the screening was successful. Eighteen of these children were found to have amblyopia. A follow-up, however, will reveal the false positives i.e. those children who managed to pass the test criterion and who were in fact amblyopic. Only then, can the success of the screening procedure be assessed.

The RYBA optotype (cited by DOLEŽALOVÁ 1964) resulted from studies done in the Second Eye Clinic in Prague. Dissatisfaction had been felt with existing pictorial optotypes particularly a newer one in use there, in which the symbols were quite indistinguishable at a distance of five metres. These were fully silhouetted symbols /

symbols (heart, apple, pear, mushroom and star) which all looked like shapeless blotches at this distance. The Ryba optotype was intended to improve on these conditions. It consisted of three simple contoured shapes, a heart, a circle, and a star, which can be used at a distance of one, two or five metres. The lines of the contours corresponded to the Snellen principle (see Fig.12 p.51). The use of this optotype raises the question of silhouette versus contoured symbols in acuity testing. It will be remembered that a similar point about the blurring effect of distance on thick black lines (especially where the lines cross) was made by Allen (1957), and for this reason he avoided crossing the lines of the images on his optotype. No silhouetted picture can conform to Snellen standards because of the absence of separation in the internal structure of the picture, but this alone does not preclude its use as a measure of visual acuity. The effect of the blurring, however, could be a serious drawback to a test particularly with children who might be less inclined to use further cues for correct recognition.

Ffooks (1965b) criticised the E test as being as much a test of visuo-spatial ability as of visual acuity in young children. He thought that visuo-spatial problems /

problems should not enter into a test because the development of this sensory dimension is relatively late. He suggested the following requirements which should be fulfilled in the construction of a valid vision test for possibly amblyopic children:-

- i. Any test should be based on the Snellen principle of angular magnification;
- ii. the choice of test objects should be adequate but not too great;
- iii. visuo-spatial problems should not enter into the test;
- iv. if fixation difficulties are present, as they are in children, the components of the letters or optotypes, should be as similar as possible, avoiding the marked difference as demonstrated by the vertical and horizontal E's.
- v. the objects presented to the child should be easily recognised and differentiated when seen. Because of this, it is recommended that a small number of different objects should be used.
- vi. at the point of non-recognition there should be a sharp cut-out and all the figures should cut-out at the same level.

Ffooks /

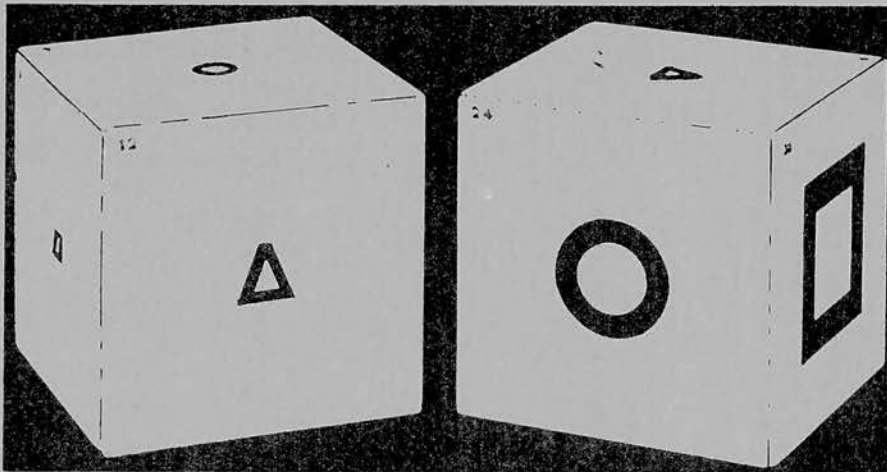


Fig. 61: The Symbol Test (Frooks 1965).

Ffooks has produced a new symbol test which he believes fulfills these requirements as nearly as possible. Three symbols (based on the optometric principle) were used: a circle, square, and triangle. The test has been produced on a cube similar to the E cube for ease of testing and two cubes have been manufactured to give two different symbols corresponding to any one size of Snellen type (see Fig.61). The child selects the appropriate shape from three plastic reproductions. This test, it is claimed, has resulted in ease and accuracy in testing the vision of children. The test is reported as being well within the child's grasp, and as the point of non-recognition occurs with a good cut-out, greater accuracy is obtained with this method (Ffooks 1965b).

In an earlier paper, Ffooks analysed the reason for the superiority of the single optotype over the row-presentation (1965a). His explanation for the phenomenon lies in the various physiological factors involved in the perceptual process. Whichever is the correct explanation, there can be no doubt about the existence of this superiority, and the use of single items in presentation is a great improvement on the overcrowded lower lines of traditional letter and picture charts. The improvement is particularly apparent /

apparent in the testing of young children whose attention cannot be focused easily on one object in an array. One recalls Ehler's remark quoted by Allen (1957) that "the sense of form is more easily utilised in an otherwise empty field".

Ffooks test is very similar to the Rybe optotype already mentioned, and there is no doubt that simplicity of a test is an essential for children. But the elements should not be so few and so dissimilar, that intelligent guessing and inference could supply the correct answer. This is the dilemma facing the test deviser ... items require to be sufficiently dissimilar to prevent the confusion of like forms common to this age group, but at the same time may not be so dissimilar that the correct answer can be obtained by elimination of forms greatly different. Perhaps Ffooks has erred a little on the latter side. One certain objection to the test is that the shapes supplied to the child for matching are made of white plastic which require to be matched against a black symbol, a discrepancy which the manufacturers appear to have overlooked.*

RABETGE /

* NOTE: This fault may since have been corrected.



Fig. 62: Rabetge Vision test (1965) for young children.

RABETGE (1965) produced a pictorial test using pairs of figures whose over-all appearance were very similar (Fig.62). Six such pairs were used, and distances of recognition were established empirically. The particular pictures chosen were found to be suitable for the young child. Also both stimuli in a pair of pictures were chosen so that their emotive content was equal; the child would therefore be equally likely to point to one as to the other. The child was first shown large single pictures of each pair and was required to learn to recognise them on presentation and to point to the appropriate figure of each pair. They had also to be encouraged to recognise the particular picture in its smaller presentations. Stories were told to make the presentations more interesting e.g. the brother and sister, and the car and the motor-bike, are racing, and the policeman is directing the bear etc. One of the pictures was then shown at a distance and the child was required to select the appropriate one. For this purpose, the six pictures were stuck onto the faces of a cube and given to the child who had to present the correct side with the appropriate picture on it. This test would appear to have an obvious appeal for the young child and would probably sustain attention and interest. The use of outline drawings also obviated the /

the blurring effect often observed on lower lines of a picture chart. However, because of the nature of the outline drawing, the optometric principle has not been adhered to. An important criticism might similarly apply to this test as to the Sheridan letter test and the Carlevaro optotype viz. the use of similar stimuli which require a differentiating matching response. It is possible that in this test the similarity of each member of the pair might supersede the points of their dissimilarity; and if the perception of the child should be governed by the over-all appearance of the pictures, confusion might result. An interesting contribution made by this test is the use of an assessment of the emotive quality of each picture in the pair to ensure that one will not be preferred over the other, and that the child's choice will be a function of his discrimination and not his natural attraction to one of the pair rather than to the other.

APPENDIX IIIFORMULAE FOR STATISTICAL PROCEDURES.Pearson's Product-moment Coefficient of Correlation (r):

$$r_{xy} = \frac{\sum xy}{N \sigma_x \sigma_y}$$

Standard Error of a Pearson Product-moment Coefficient of Correlation (σ_r):

$$\sigma_r = \frac{1 - r^2}{\sqrt{N - 1}}$$

The Arithmetic Mean (M):

$$M = \frac{\sum X}{N}$$

Standard Deviation (σ):

$$\sigma = \sqrt{\frac{\sum x^2}{N}}$$

Standard Error of Mean (σ_M):

$$\sigma_M = \sqrt{\frac{\sum x^2}{N(N - 1)}}$$

Standard Error of Standard Deviation (σ_σ):

$$\sigma_\sigma = \frac{\sigma}{\sqrt{2N}}$$

The t Test of a Difference between Means of Samples of Unequal Size (t):

$$t = \frac{M_1 - M_2}{\sqrt{\left(\frac{\sum x_1^2 + \sum x_2^2}{N_1 + N_2 - 2} \right) \left(\frac{N_1 + N_2}{N_1 N_2} \right)}}$$

Point-Biserial Correlation (r_{pbi}):

$$r_{pbi} = \frac{M_p - M_q}{\sigma_t} \sqrt{pq}$$

Analysis of Variance - One-Way Classification:

Deviation of a set mean from the total mean:

$$d = M_s - M_t$$

Between variance or mean square:

$$V_b = \frac{n \sum d^2}{k - 1}$$

Within variance or mean square:

$$V_w = \frac{\sum x_s^2}{k(n - 1)}$$

F ratio:

$$F = \frac{\text{Between variance}}{\text{Within variance}}$$

Standard Error of a Percentage (σ_P):

$$\sigma_P = \sqrt{\frac{PQ}{N}}$$

The Coefficient of Multiple Correlation (R) - 3-variables:

$$R^2_{1.23} = \frac{r^2_{12} + r^2_{13} - 2r_{12}r_{13}r_{23}}{1 - r^2_{23}}$$

$$\beta_{12.3} = \frac{r_{12} - r_{13}r_{23}}{1 - r^2_{23}}$$

(Standard partial regression coefficients)

$$\beta_{13.2} = \frac{r_{13} - r_{12}r_{23}}{1 - r^2_{23}}$$

$$b_{12.3} = \left(\frac{\sigma_1}{\sigma_2} \right) \beta_{12.3}$$

(Partial regression coefficients)

$$b_{13.2} = \left(\frac{\sigma_1}{\sigma_3} \right) \beta_{13.2}$$

Standard Error of a Multiple R (σ_R):

$$\sigma_R = \frac{1 - R^2}{\sqrt{N - m}}$$

Standard Error Of a Difference between Percentages (σ_{dp}):

$$\sigma_{dp} = \sqrt{\sigma_{P_1}^2 + \sigma_{P_2}^2 - 2r_{12}\sigma_{P_1}\sigma_{P_2}}$$

A \bar{z} Test for a Difference between Uncorrelated Proportions(\bar{z}):

$$\bar{z} = \frac{p_1 - p_2}{\sqrt{p\bar{q}} \left(\frac{N_1 + N_2}{N_1 N_2} \right)}$$

Correction Factor for \bar{z} Test between Proportions:

$$\bar{z} = \frac{1}{2} \left(\frac{N_1 + N_2}{N_1 N_2} \right)$$

The z Test of Differences between Correlation Coefficients (z):

$$\sigma_{dz} = \sqrt{\frac{1}{N_1 - 3} + \frac{1}{N_2 - 3}} \quad \text{(Standard Error of a difference between two } z \text{ coefficients)}$$

Spearman's Rank-difference Coefficient of Correlation (ρ):

$$\rho = 1 - \frac{6\sum D^2}{N(N^2 - 1)}$$

Chi-Square (χ^2):

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e} \right]$$

Computing the Pearson r from a Scatter Diagram (r):

$$r_{xy} = \frac{\sum x'y' - (M_{x'}M_{y'})}{(\sigma_{x'})(\sigma_{y'})}$$